

**UNIVERSITY OF CINCINNATI  
COLLEGE OF ENGINEERING**

**Department of Civil and Environmental Engineering**

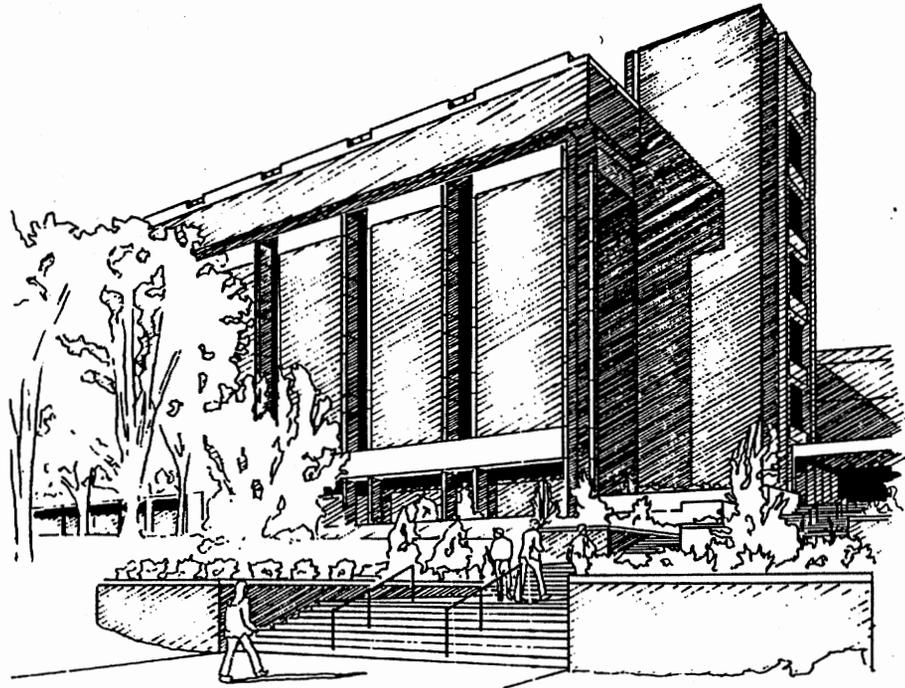
**Ohio Route 50 Joint Sealant Experiment  
Phase 1 Construction Report  
(1997-98)**

Prepared for  
Ohio Department of Transportation and  
Federal Highway Administration  
*State Job No.: 14668(0); Contract No.: 8527*

*March 1999*

**A.M. Ioannides and I.A. Minkarah (co-PIs)  
Bryan K. Hawkins and Jason Sander (Research Assistants)**





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by

**University of Cincinnati  
Cincinnati Infrastructure Institute  
Department of Civil and Environmental Engineering  
Cincinnati, OH**

March 1999

Research Team: A.M. Ioannides and I.A. Minkarah (*co-PIs*)  
Bryan K. Hawkins and Jason Sander (*Research Assistants*)

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# 1 INTRODUCTION

## 1.1 Introduction

Following a 1992 tour of several European countries by a variety of pavement engineers from the United States, a program was formulated by the Federal Highway Administration (FHWA), whose aim is to assess the effectiveness of a number of innovative features, including worthwhile European concepts and practices, in improving rigid pavement performance in this country. The ultimate aim is the design and construction of High Performance Rigid Pavements (HPRP), characterized by the following three attributes:

1. Incorporating innovative design features and materials ;
2. Enhancing construction processes so that productivity and quality are simultaneously improved ; and
3. Prolonging service life, thereby lowering life cycle costs.

The specific HPRP project described herein is concerned with concrete pavement joint sealants. It is desirable to acquire a better understanding of the performance of various sealant types used in conjunction with a variety of geometric configurations, in order to optimize pavement cost and performance. An equally significant objective of this experiment is to contribute toward an engineering appreciation concerning the necessity of joint sealing in concrete

pavements. This report documents the first phase of the construction of a joint sealant test site near Athens, OH during the 1997-98 construction season.

## **1.2 Problem Statement**

Since the early 1940s, joint sealants have been an integral part of practically all jointed plain concrete pavements (JPCP) or jointed reinforced concrete pavements (JRCP). Previous studies in Ohio and elsewhere have demonstrated that joint sealing techniques may make a significant contribution to the performance of such pavements. Sealants are considered to provide protection to the pavement in two important ways. First, by sealing joints, infiltration of moisture into the pavement base and subgrade is reduced. Such moisture would otherwise lead to softening, pumping, and erosion of these layers, resulting in joint faulting and corner breaks in the slab. Secondly, the sealing of joints prevents incompressible materials, such as small stones, from entering the joints and becoming lodged. Such incompressibles can inhibit thermal slab movement, increasing the stresses in pavement slabs and leading to joint spalling and transverse cracking.

Serious consideration, however, must be given to the practical aspects of joint sealing in concrete pavements if the sealant is to work effectively. Most importantly, the process of sealing joints requires careful and experienced installation and inspection. The joint must be washed, sandblasted, and cleaned before the backer rod and sealant are applied, in order to prepare vertical, intact and clean bonding surfaces that are dry and free of contaminants. If proper construction procedures are not followed carefully, the sealant may not form a good bond with

the concrete slab and infiltrating moisture may not be reduced as effectively. Improperly installed sealants are also subject to premature deterioration from weather and traffic. If the sealants are installed too low from the pavement surface, incompressibles are likely to enter the joint openings. Conversely, if installed at or slightly above the pavement surface, vehicle tires are likely to damage or destroy the sealant. The sealant must also be installed under suitable weather conditions, with virtually no moisture present in any form. In addition, if the temperature is at or below 4°C (40°F) during joint sealing, additional precautions must be taken. Given the stringency of cleaning and installation procedures, it is advisable to have someone inspecting these operations as they proceed. Without such inspection, a great deal of effort and money could be wasted on ineffective seals.

The economics of sealing joints is another consideration. Joint sealing accounts for considerable expense during the construction of new pavements, and there is a need to determine the economic benefits, if any, this operation provides. The experiment described in this Report is intended to address this issue and to generate practical conclusions in the context of the on-going debate over the cost-effectiveness of sealing joints.

Another expected contribution of this project pertains to its location in the Wet-Freeze Zone. This is one of the major climatic zones of the United States, yet it is not represented in the on-going Strategic Highway Research Program (SHRP) SPS-4 experiment, developed to answer questions about joint sealing effectiveness, materials, and methods. It is, therefore, desirable to add a test site in this climatic region so that the effects unique to the region can be assessed directly. Information from the Athens, OH site along with results from other SPS-4 sites, will allow a more complete analysis of the role of joint sealing in pavements.

### **1.3 Project Objectives**

The experimental design for this project was developed in 1997 by the Federal Highway Administration (FHWA) and the Ohio Department of Transportation (ODOT). It involves the construction of an experimental stretch of pavement, which will provide data for the evaluation of the performance of various joint seals and joint configurations. Unsealed control sections are also included. In constructing the test sections, the following objectives were established:

- (a) To assess the effectiveness of a variety of joint sealing practices employed after the initial sawing of joints, and to examine their repercussions in terms of reduced construction time and life cycle costs;
- (b) To identify those materials and procedures that are most cost effective; and
- (c) To determine the effect of joint sealing techniques on pavement performance.

### **1.4 Project Location and Description**

The test site under investigation is a 10.5-km (6.5-mile), four-lane divided highway constructed along a stretch of US Route 50 in Athens County, OH. Figure 1.1 illustrates the specific location of the project. This new four-lane highway has a twenty year design period, with current (1993) average daily traffic (ADT) of 7820 and design year (2013) ADT of 10950 (ODOT, 1995a). The eastbound lanes were constructed during the first construction phase

(1997-98 season), while traffic was served by the existing highway pavement, which comprises only two 3.7-m (12-ft) lanes. Upon completion, traffic was diverted onto the newly constructed pavement, to permit the reconstruction of the existing lanes. The existing two lanes will be torn out during the second construction phase (1998-99 season), to be replaced with new construction, which will form the westbound lanes of the new highway.

The project is located in the Wet-Freeze climatic zone. The local mean annual precipitation is 1-m (40 in.); while the mean annual snowfall is 620-mm (24 in.). The mean monthly average temperature is 12°C (53°F), with a low average monthly temperature of 0°C (32°F), and a high average monthly temperature of 24°C (75°F). This information is from *Climatic Atlas of the United States* (1983), and is based on thirty years of collected data.

The new pavement cross-section consists of a 250-mm (10-in.) plain, jointed, wire-reinforced Portland cement concrete (PCC) slab (Item 451), placed over a 100-mm (4-in.) crushed aggregate, well-graded, free-draining base layer (Special Item: "New Jersey base"), constructed over a 150-mm (6-in.) crushed aggregate subbase (Item 304), resting over the predominantly silty clay local subgrade. Figures 1.2 and 1.3 show the cross-section of the proposed test sections. Appendix A provides ODOT (1994; 1995b) construction specifications concerning the proposed pavement.

The new highway consists of two 3.7-m (12-ft) wide lanes in each direction, incorporating tied PCC shoulders of variable width. The shoulders are 3-m (10-ft) wide on the outer side, and 1.2-m (4-ft) wide on the inner side (adjoining the median). Transverse joints perpendicular to the direction of traffic are provided at 6.4-m (21-ft) spacing. Epoxy-coated steel dowels of 38 mm (1.5 in.) in diameter, and 460 mm (18 in.) in length, supported on baskets, are installed on 305-

mm (12-in.) centers, beginning 150 mm (6 in.) from the longitudinal joint. The longitudinal centerline joint is tied with 16-mm (5/8-in.) round, deformed bars with a length of 760 mm (30 in.) and spaced at 760 mm (30 in.), center-to-center. These specifications are in accordance with the ODOT (1994) Standard Construction Drawings, which are also included in Appendix A.

## **1.5 Preliminary Literature Survey**

A preliminary literature review on the subject of joint sealing reveals that similar conclusions are generally reached by most authors. First, there is a consensus as to the purpose of joint sealing, namely to minimize moisture infiltration into the pavement system and to keep incompressible debris from accumulating in the joints. The detrimental effects of the presence of excess moisture within any of the pavement layers, including those of the subgrade, are well documented. The multiplicity of associated distresses suggests that providing effective means of protection against the infiltration of moisture and for expeditious drainage are significant if often ignored pavement design considerations. Unfortunately, it is not practical to construct and maintain a completely water-tight pavement system. Consequently, joint sealants are currently used in highway pavements in order to minimize passage of surface water through joints and cracks, in conjunction with a permeable subbase designed to remove water from the pavement system (Voigt, 1997). This leads to the question of whether both these lines of defense are necessary, or whether it might be more cost effective not to seal the joints, and to rely instead on the permeable subbase and on other associated subsurface drainage features to remove the water. The answer to this question has been the subject of increasing controversy in the United States in

recent years.

In a survey of state highway agencies, the following philosophies on drainage were recorded. Thirty states strive to seal pavements as well as possible, while also attempting to control the water through use of a drainage layer, other subsurface drainage, or both. Nine states try to seal the pavement as well as possible, but are not concerned with subsurface drainage. The remaining eleven states take the position that water will inevitably enter the pavement system, and seek only to control it through use of a drainage layer, other subsurface drainage, or both, rather than relying on the effectiveness of joint sealants. Only one of these eleven states, Wisconsin, dispenses with joint sealing entirely (McGhee, 1995).

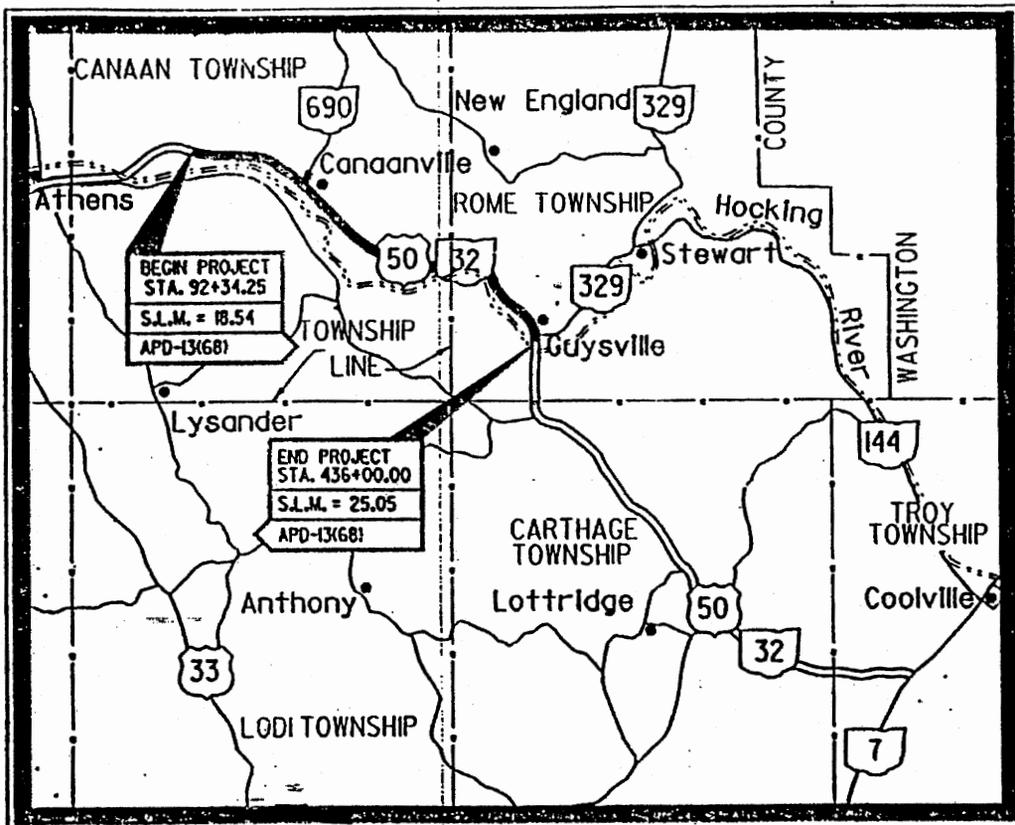
If joint sealing is to be effective as a means of preventing excess moisture from infiltrating the pavement system, the preparation of the joint and installation techniques appropriate to each sealant type are of primary importance. Perhaps the biggest obstacle that must be overcome when installing any pavement joint seal is making sure that the joint is both clean and dry prior to installing the seal (Nee and Klosowski, 1997). Manufacturer specifications for the cleaning of joints and installation of each product should be followed closely. It is also advisable to have someone present for the inspection of the joint sealing procedures, which usually involve flushing the joint with high water pressure equipment, sandblasting both faces of the joint, and cleaning with compressed air prior to sealant installation. Forensic investigations have led to the identification of the most likely causes of pavement seal problems, a list of which is given below (Nee and Klosowski, 1997):

1. Climatic conditions before, during, and immediately following sealant installation;

2. The sealant itself, i.e., either less than ideal product properties or the wrong sealant for the application;
3. Deficient installation practices;
4. Incompatibility of the sealant with underlying pavement layers or the environment.

In view of the significant variability encountered during highway pavement construction, an intensive inspection program during the joint preparation and installation of joint seals is essential for ensuring that the effort and money invested in such procedures are not wasted on ineffective seals. If pavement seals are to provide significant protection to a pavement system, this will depend primarily on how carefully and correctly the sealant is installed.

# ATHENS COUNTY CANAAN & ROME TOWNSHIPS



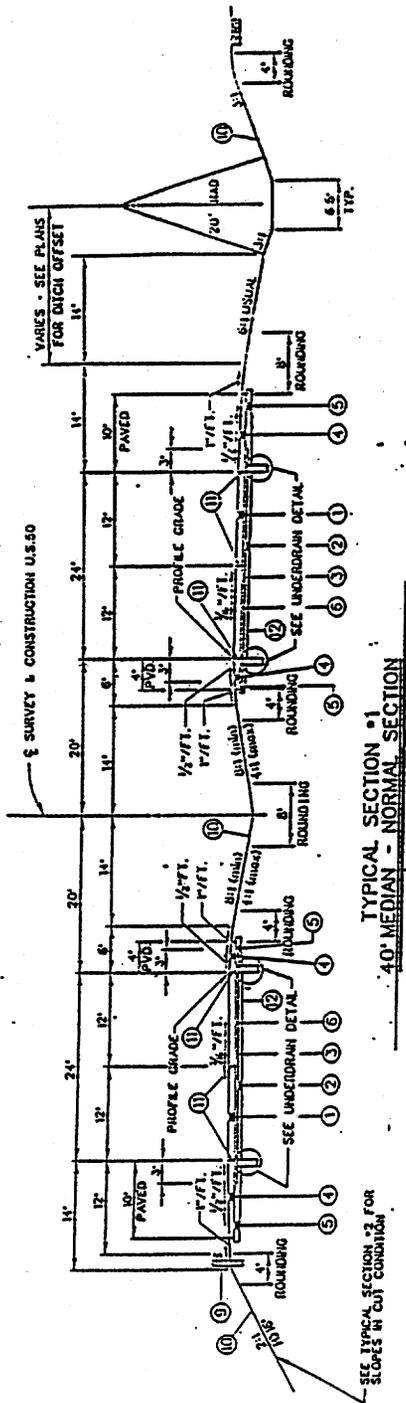
## LOCATION MAP



Fig. 1.1 Location of construction project

# TYPICAL SECTIONS

## TYPE 451 ON FREE DRAINING BASE



### LEGEND

NO.	ITEM	DESCRIPTION
1	451	10" REINFORCED CONCRETE PAVEMENT, AS PER PLAN (SEE SHEET M)
2	304	8" AGGREGATE BASE
2A	304	AGGREGATE BASE GRADING, AS PER PROPOSAL NOTE
3	SPEC	4" ASPHALT TREATED FREE DRAINING BASE
4	452	PLAN CONCRETE SHOULDERS, VARIABLE DEPTH (SEE DETAIL SHEET 13), AS PER PLAN (SEE SHEET M)
4A	452	10" PLAN CONCRETE PAVEMENT, AS PER PLAN (SEE SHEET M)
5	304	AGGREGATE BASE, VARIABLE DEPTH (SEE DETAIL SHEET 13)
6	408	UNIFORM PRIME COAT (0.4 GAL./SQ.)
7		FILTER FABRIC UNDERDRAIN WRAP 712.09 TYPE A
8	805	4" PCC UNDERDRAIN 707.15 WITH FABRIC WRAP, AS PER PLAN (SEE SHEET 13)
9	606	GUARDRAIL, TYPE 5
10	659	SEEDING & MULCHING
11		STANDARD LONGITUDINAL JOINT, AS PER BP-2.1
12	203	SUBGRADE COMPACTION

ITEM 451 10" REINFORCED CONCRETE PAVEMENT, AS PER PLAN

ALL COARSE AGGREGATE USED FOR THIS ITEM SHALL BE APPROVED SIZE 57 AND SHALL BE APPROVED BY THE LABORATORY. APPROVAL OF ALL COARSE AGGREGATE SHALL BE OBTAINED UNDER THE CURVE IN ACCORDANCE WITH ASTM C 666 PROCEDURES. THE TEST SPECIMENS VERSUS THE NUMBER OF TEST CYCLES SHALL NOT EXCEED 2.05 AT 30 OR LESS CYCLES.

QUANTITIES PER CUBIC YARD WILL BE IN ACCORDANCE WITH 499.03 CONCRETE TABLE OF SPECIFICATIONS.

FINE AGGREGATE FOR THIS ITEM SHALL CONTAIN NOT LESS THAN 25 PERCENT OF SILICEOUS PARTICLES AS DETERMINED BY THE INSOLUBLE RESIDUE TEST ON FILE AT THE LABORATORY. ALL OTHER PROVISIONS OF 451 SHALL REMAIN IN EFFECT.

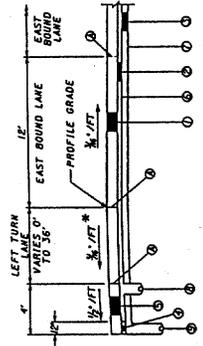
Fig. 1.2 Typical cross-section of highway

# TYPICAL SECTION DETAILS

REVISED BY ODOT 10-1-88

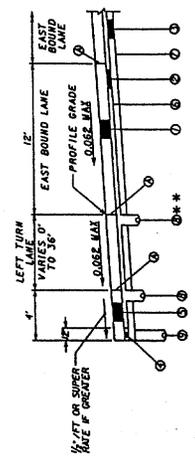
## LEGEND

- ① ITEM 451 - 10" REINFORCED CONCRETE PAVEMENT, AS PER PLAN
- ② ITEM SPECIAL - 4" NON-STABILIZED DRAINAGE BASE, TYPE 1A (SEE SHEET 18C1) OR ITEM 452 - 4" STABILIZED DRAINAGE BASE, TYPE 1A (SEE SHEET 18C1)
- ③ ITEM 304 - 4" AGGREGATE BASE
- ④ ITEM 452 - 10" PLAIN CONCRETE PAVEMENT, AS PER PLAN
- ⑤ ITEM 408 - BITUMINOUS PRIME COAT APPLIED AT 0.4 GAL/SY
- ⑥ ITEM 403 - SURGRADE COMPACTION
- ⑦ ITEM 605 - 4" SHALLOW PIPE UNDERDRAIN, AS PER PLAN
- ⑧ LONGITUDINAL JOINT
- ⑨ FUTURE FABRIC UNDERDRAIN WRAP, TIZOS, TYPE A PAVEMENT INCLUDED WITH ITEM 605 - 4" SHALLOW PIPE UNDERDRAIN, AS PER PLAN



**NORMAL SECTION**  
STATIONING: STA. 94+50.00 TO 101+43.00 - 693.00'  
STA. 104+40.00 TO 105+23.00 - 83.00'  
STA. 172+90.00 TO STA. 187+84.45 - 1794.45'  
STA. 243+00.00 TO 258+60.00 - 1526.00'

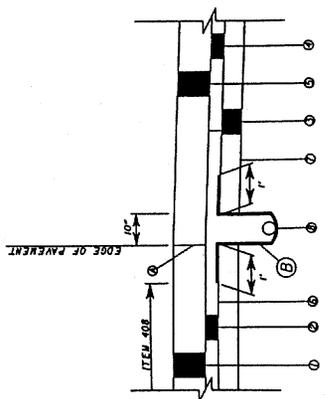
\* SEE INTERSECTION DETAILS FOR PAVEMENT AREAS IN INTERSECTION AREAS



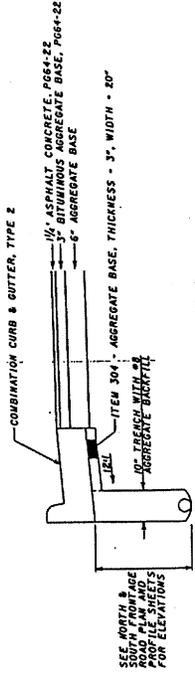
**SUPER-ELEVATED SECTION**  
STATIONING: STA. 243+40.00 TO 258+60.00 - 1320.00'  
STA. 332+60.00 TO 333+00.00 - 340.00' (RIGHT TURN LANE)  
STA. 104+40.00 TO 111+34.28 - 694.28'  
STA. 112+40.00 TO 113+23.00 - 83.00'  
STA. 172+90.00 TO STA. 187+84.45 - 1794.45'  
STA. 243+40.00 TO 258+60.00 - 1320.00'  
STA. 328+60.00 TO 333+40.00 - 1794.00' (RIGHT TURN LANE)

\*\* EAST BOUND LANES ONLY

## USR 50 LEFT TURN LANES



USR 50 MAIN LINE



FRONTAGE ROADS

## UNDERDRAIN DETAILS

NOTES:  
1. PAVEMENT ELEVATIONS AND ELEVATIONS, SEE PAVEMENT DETAIL SHEETS 58-59.  
2. FOR PAVEMENT WARPING OF FULL DEPTH, SEE SHEETS 72-93, 94-95, 96-97, 98-99, 100-101, 102-103, 104-105, 106-107, 108-109, 110-111, 112-113, 114-115, 116-117, 118-119, 120-121, 122-123, 124-125, 126-127, 128-129, 130-131, 132-133, 134-135, 136-137, 138-139, 140-141, 142-143, 144-145, 146-147, 148-149, 150-151, 152-153, 154-155, 156-157, 158-159, 160-161, 162-163, 164-165, 166-167, 168-169, 170-171, 172-173, 174-175, 176-177, 178-179, 180-181, 182-183, 184-185, 186-187, 188-189, 190-191, 192-193, 194-195, 196-197, 198-199, 200-201, 202-203, 204-205, 206-207, 208-209, 210-211, 212-213, 214-215, 216-217, 218-219, 220-221, 222-223, 224-225, 226-227, 228-229, 230-231, 232-233, 234-235, 236-237, 238-239, 240-241, 242-243, 244-245, 246-247, 248-249, 250-251, 252-253, 254-255, 256-257, 258-259, 260-261, 262-263, 264-265, 266-267, 268-269, 270-271, 272-273, 274-275, 276-277, 278-279, 280-281, 282-283, 284-285, 286-287, 288-289, 290-291, 292-293, 294-295, 296-297, 298-299, 300-301, 302-303, 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## 2 EXPERIMENTAL PLAN

### 2.1 General

This research experiment involves the installation of various joint sealants in the transverse joints of a newly constructed PCC pavement. Fifteen material-joint configurations are used in the experiment. The purpose of these pavement test sections is to complement similar sections constructed in other states under the SHRP SPS-4 experiment.

### 2.2 Test Sections

Between Sta 154+00 and 290+00 in the eastbound direction and between Sta 133+60 and 290+00 in the westbound direction, the pavement is divided into fifteen test sections, each section typically being 180 m (600 ft) in length. The stretch from Sta 231+00 to 260+00 corresponds to the location of the batch plant and of the headquarters of the project contractor (*Kokosing Construction Company, Inc.*). Due to expected truck traffic, this stretch is excluded from the test sections. Each test section will incorporate about thirty joints. The experimental design calls for two replicates of each of fifteen chosen material-joint configuration combinations. Two of these combinations involve unsealed joints. In each case, one replicate is in the eastbound lanes, constructed in the 1997-98 construction season, and the other in the westbound lanes, to be constructed in the 1998-99 construction season. The joint configuration details are numbered one

through six and are shown in Fig. 2.1.

### **2.3 Changes in Experimental Plan**

The original experiment plan for the eastbound lanes, as outlined in the proposal submitted to ODOT by the University of Cincinnati research team, is shown in Table 2.1. This includes sealant materials, start and end stations, and joint configuration numbers. Several changes have been made, however, to this plan. Two test sections, from Sta 154+00 to 160+00 in the eastbound and from Sta 133+60 to 139+60 in the westbound lanes, have been added, to be sealed using the TechStar W-050 compression seal in joint configuration number 5. Two of the sealants designated in the proposal are no longer manufactured. These sealants, Mobay Baysilone 960-SL self-leveling silicone and Dow 888-SL self-leveling silicone, were replaced with Crafc0 903-SL self-leveling silicone and Dow 888 non-sag silicone, respectively. During the construction of the eastbound lanes in the 1997-98 season, however, the Mobay Baysilone 960-SL was actually replaced instead by the Crafc0 902 non-sag silicone sealant between Sta 200+00 and 206+00. The University of Cincinnati research team has been unable to determine the reason for this substitution. Table 2.2 presents the 'as constructed' matrix of sealant materials, start and end stations, and joint configuration numbers for the test sections in the eastbound lanes.

## 2.4 Joint Sealants

Nine different joint sealants are used in the test sections, in addition to those intentionally left unsealed. Of the nine sealant types, two are single component, hot-applied sealants, four are silicone sealants, and three are pre-formed compression seals. Product literature obtained from the various sealant manufacturers is assembled in Appendix B.

The two hot-applied sealants are both manufactured by *Crafco Inc.* of Chandler, AZ. The first is the Crafco Superseal 444/777, a fuel resistant sealant specifically intended for sealing PCC pavements in moderate to hot climates. This sealant is initially liquid and is poured into a melter application unit, which heats the sealant to the application temperature. The sealant is then applied to prepared joints. Joint preparation includes flushing with water, sandblasting both faces of the joint, and cleaning with compressed air. The product data sheet included in Appendix B advises that this sealant is not to be used in asphalt concrete (AC) pavements or extreme jet blast areas, and should only be applied when ambient air temperature is between 10°C (50°F) and 32°C (90°F).

The second hot-applied sealant used is the Crafco Roadsaver 221. This petroleum-based pavement crack and joint sealant can be used in both AC and PCC pavements and is intended for use in moderate to cooler climates. It is initially in solid block form, and is heated before application using either a pressure feed melter applicator unit or a pour pot. The product data sheet recommends that application should be at pavement temperatures of 4°C (40°F) or higher, and that the joint should be shaped so that the sealant reservoir depth-to-width ratio does not exceed 2:1. It is also stated that “for best performance, cracks or joints should be cleaned using

appropriate routing, brushing, or blowing operations to provide intact bonding surfaces which are free from all dust, moisture, or other contaminants.”

Of the four silicone sealants used, two are manufactured by *Crafco, Inc.* of Chandler, AZ. The first is the Roadsaver Silicone SL (Crafco 903-SL), a self-leveling, jet-blast resistant, silicone sealant that can be used in all climates. The product data sheet claims that it maintains field serviceability when exposed to intermittent fuel and oil spills, and is designed to be used in all types of concrete pavement joint applications. It is applied using a bulk dispensing system unit, requires no tooling nor the use of primers, and is able to seal joints in “green” concrete, i.e., at a relatively early stage of curing. Joint preparation includes flushing with water, sandblasting both faces of the joint, and cleaning with compressed air.

The second silicone joint sealant manufactured by *Crafco, Inc.* is the Roadsaver Silicone Sealant (also called Crafco 902). This is a low modulus, non-sag silicone sealant intended for use in PCC pavements. It possesses the same qualities as the Crafco 903-SL, except that it is not self-leveling but must be tooled to ensure adequate contact and adhesion with the joint walls. As noted earlier, this sealant was not included in the original plan for this experiment.

The other two silicone sealants used are manufactured by *Dow Corning Corporation* of Midland, MI. The first is the Dow 888, a one-part, cold-applied silicone joint sealant designed for use in PCC pavement applications. It requires no use of primers and is virtually unaffected by sunlight, rain, snow, ozone or temperature extremes. The product data sheet recommends that the sealant should not be applied to damp concrete or installed in inclement weather. Since it is a non-sag silicone sealant, it must be tooled to ensure adequate contact and adhesion to an appropriate depth. It is applied directly from a bulk container into the joint by hand or with an

air-powered pump.

The last silicone sealant is the self-leveling, one-part, cold-applied Dow 890-SL, designed to be used in both AC and PCC pavements. It requires no use of primers and is resistant to climatic extremes. It has the same restriction as the Dow 888, i.e., it should not be applied if moisture is present in any form. Since it is self-leveling, it requires no tooling and is applied using a hand or air-powered pump.

Turning now to the compression seals included in this experiment, the Delastic V-687 compression seal is manufactured by *The D.S. Brown Company* of North Baltimore, OH and has a width of 17.5-mm (11/16-in.). It is a preformed Neoprene compression seal and is installed with the help of an adhesive lubricant, either by hand or with the help of an installation machine. The data sheet advises that the seal must be installed with 3% or less stretch to prevent premature failure. Joint preparation recommendations call for washing the joint with water and cleaning it with compressed air. Sandblasting may sometimes be called for, as well. Preparation procedures also require that the joint face must be perpendicular to the surface of the pavement and that any spalling must be repaired prior to sealant installation. The data sheet on this product calls for inspection during installation of the percent stretch of the seal, and of the depth of the seal, as well as for visual inspection for any twists, cuts, pop-ups, etc.

The TechStar W-050 W-Seal is manufactured by *TechStar, Inc.* of Findlay, OH. This seal is made of Santoprene thermoplastic and is installed after a TechStar adhesive has been applied to the joint. The seal is initially flat but it is folded as it is fed into an installation tool, which inserts the seal into the adhesive-lined joint. Information provided by the manufacturer claims that this seal is stretch-proof and requires less recess from the pavement surface than other seals.

Installation procedures recommended include air blowing the joints and applying the adhesive to the vertical surfaces of the joints.

The final compression seal used is manufactured by *Watson Bowman Acme* of Amherst, NY. In the eastbound lanes, the experimental plan called for the WB-687 compression seal, whereas in the westbound lanes the WB-812 was called for. These are preformed neoprene compression seals, distinguished mainly in their width and height dimensions: the WB-687 is 17 mm (11/16 in.) wide by 17 mm (11/16 in.) high, whereas the WB-812 is 21 mm (13/16 in.) wide by 22 mm (7/8 in.) high (see Appendix B). The recommended installation procedures include cleaning the joint with compressed air and applying BonLastic adhesive to the inner faces of the joint. The sealant is then to be placed along the joint and compressed into place to the desired depth.

## **2.5 Joint Configurations**

Six joint configurations are used in this experiment, as shown in Fig. 2.1. The initial sawcut for joint configurations 1 through 5 is specified as 83 mm (3-1/4 in.) deep and 3 mm (1/8 in.) wide. Of these, joint configurations 2 and 4 receive no secondary cut: joint configuration 2 is left unsealed in the control sections, and joint configuration 4 is filled with a 6-mm (1/4-in.) backer rod and 5 mm (3/16 in.) to 8 mm (5/16 in.) of self-leveling silicone sealant. Joint configuration 1 has a secondary cut, 10 mm (3/8 in.) wide and 38 mm (1-1/2 in.) deep. This is designed to accommodate the 13-mm (1/2-in.) backer rod and 6 to 10-mm (1/4 to 3/8-in.) of hot pour or silicone sealant material. Joint configuration 3 has a secondary cut, 6 mm (1/4 in.) wide

and 25 mm (1 in.) deep, to accommodate an 8-mm (5/16 in.) backer rod and 6 to 10 mm (1/4 to 3/8 in.) of self-leveling silicone sealant material. Joint configuration 5 has a 9.5-mm (3/8-in.) wide by 38-mm (1-1/2-in.) deep secondary cut to accommodate a compression seal. The initial cut for joint configuration 6 is 6 mm (1/4 in.) wide and 83 mm (3-1/4 in.) deep. This configuration receives no secondary cut and is left unsealed. All joint configurations have a +/- 2-mm (1/16-in.) tolerance on width; joint configurations 1, 3, and 4, in which backer rods are inserted, require a 6- to 10-mm (1/4 to 3/8-in.) recess between the top of the sealant and the surface of the pavement, to avoid contact of vehicle tires with the silicone seals.

## **2.6 Joint Specifications**

Specifications for the preparation of joints and installation of sealants are provided under Section 451.13 of the 1995 ODOT *Construction and Material Specifications* Manual (ODOT, 1995b). Section 451.08 of the same Manual gives specifications for the sawing of joints; specific guidelines for the installation of each product, including the use of backer rod, are provided in Section 705. These guidelines are reproduced in Appendix A. All requirements specified for sealing transverse joints in the PCC slab (Item 451) per ODOT (1995b) and Standard Drawing BP-2.2 (ODOT, 1994) are applicable, modified in accordance with the experimental plan in Table 2.2. The backer rod is to meet the requirements of Section 705.02 of ODOT (1995b), except that the diameter is to be as shown in Fig. 2.1. Joint sealants are to be installed in accordance with the manufacturers' recommendations in joints whose dimensions are to be as shown in Fig. 2.1.

**Table 2.1** Original experimental plan (eastbound lanes)

<b>Sealant Material</b>	<b>Begin Station</b>	<b>End Station</b>	<b>Joint Configuration</b>
No sealant	160+00	166+00	6
DOW 890-SL self leveling silicone	166+00	172+00	3
Crafco 444 hot pour	172+00	188+00	1
Crafco 903-SL self-leveling silicone	188+00	194+00	1
Watson Bowman WB-687 compression seal	194+00	200+00	5
Mobay Baysilone 960-SL self-leveling silicone	200+00	206+00	1
Crafco 903-SL self-leveling silicone	206+00	213+00	4
Dow 890-SL self-leveling silicone	213+00	219+00	4
No sealant	219+00	225+00	2
Delastic V-687 compression seal	225+00	231+00	5
Crafco 221 hot pour	260+00	266+00	1
Dow 890-SL self leveling silicone	266+00	272+00	1
Dow 888-SL self-leveling silicone	272+00	284+00	1
Dow 888 non-sag silicone	284+00	290+00	1

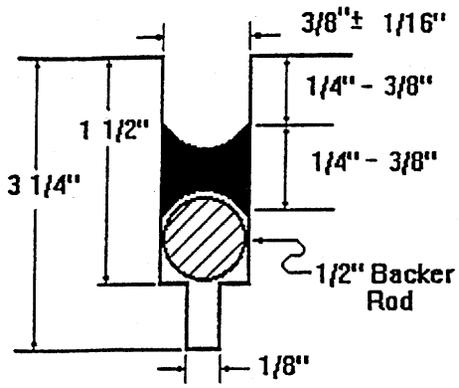
**Table 2.2** Sealant material, location and joint configuration for eastbound lanes (as constructed)

Sealant Material	Begin Station	End Station	Joint Configuration
TechStar W-050 <sup>1</sup>	154+00	160+00	5
No sealant	160+00	166+00	6
DOW 890-SL self leveling silicone	166+00	172+00	3
Crafco 444 hot pour	172+00	188+00	1
Crafco 903-SL self-leveling silicone	188+00	194+00	1
Watson Bowman WB-687 compression seal	194+00	200+00	5
Crafco 902 non-sag silicone <sup>2</sup>	200+00	206+00	1
Crafco 903-SL self-leveling silicone	206+00	213+00	4
Dow 890-SL self-leveling silicone	213+00	219+00	4
No sealant	219+00	225+00	2
Delastic V-687 compression seal	225+00	231+00	5
Crafco 221 hot pour	260+00	266+00	1
Dow 890-SL self leveling silicone	266+00	272+00	1
Dow 888 non-sag silicone <sup>3</sup>	272+00	284+00	1
Dow 888 non-sag silicone	284+00	290+00	1

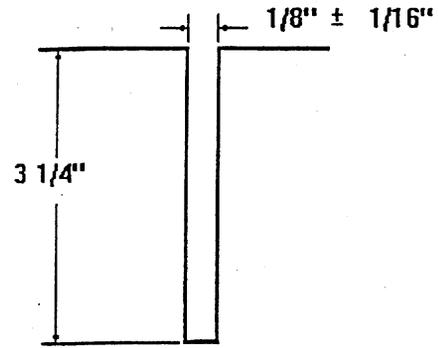
<sup>1</sup> This section was added to the test sections after the initial proposal.

<sup>2</sup> This section was originally to be sealed with Mobay Baysilone 960-SL. This product is no longer manufactured, however, and the revised plan calls for this section to be sealed with Crafco 903-SL. As constructed, the section was actually sealed with Crafco 902, a non-sag silicone sealant, for reasons unknown to the research team.

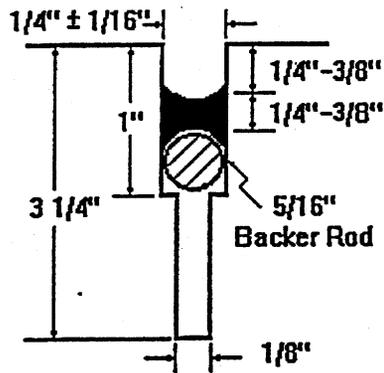
<sup>3</sup> This section was originally to be sealed with Dow 888-SL, which is no longer manufactured.



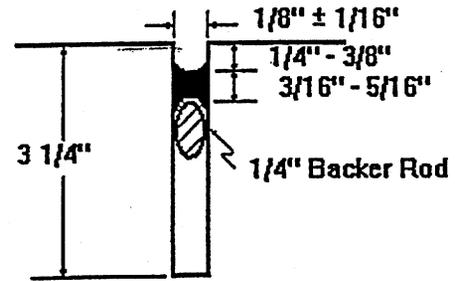
Detail 1



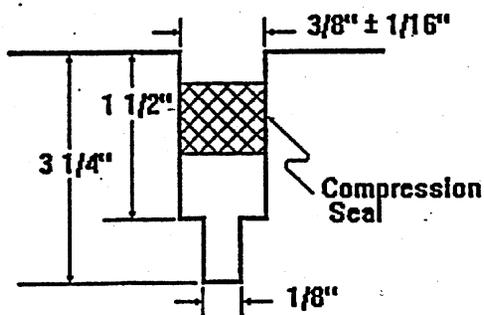
Detail 2



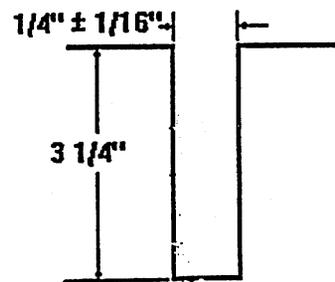
Detail 3



Detail 4



Detail 5



Detail 6

Fig. 2.1 Joint configuration details

### **3 CONSTRUCTION OF EASTBOUND LANES**

#### **3.1 Construction Procedures**

##### **3.1.1 General Overview**

Construction of the new eastbound lanes began on June 3, 1997, following a ground-breaking ceremony reported in the local press (Fig. 3.1). Placement of the PCC slab in the test sections took place between 10/16 and 10/22/97, with initial saw cuts made a few hours after paving, as soon as the slab was capable of supporting the saw.

Secondary saw cuts were made a day or two before joint sealing, which occurred from the end of October through early November, 1997.

*Kokosing Construction Company, Inc.* was responsible for all construction procedures, which included subgrade preparation; subbase, base and PCC slab placement; sawing and cleaning of joints; and installation of backer rods and sealants. Each of these tasks is described below.

##### **3.1.2 Subgrade Preparation**

Compaction specifications are found in Sections 203.12 and 203.13 of the ODOT (1995b) Manual, and are reproduced in Appendix A. As noted earlier, the subgrade encountered in this area is mostly a brown and gray silty clay, AASHTO classification A-6(11) and A-7-6(15), with some sand and gravel. The contract for this project calls for

the upper 0.3 m (1 ft) of subgrade to be compacted and brought to grade. The minimum compaction requirement was 100% of the standard Proctor maximum dry unit weight (AASHTO T-99). A Troxler Nuclear Density Gage was used by ODOT technicians to measure the in situ soil unit weight and water content.

### **3.1.3 Subbase Placement**

The subbase consists of a 150-mm (6-in.) lift of crushed, well-graded aggregate (Item 304), purchased from a local coal strip mine. Pertinent specifications are those for aggregate bases, found in Section 304 of the ODOT Manual (1995b) and reproduced in Appendix A. In order to determine the compaction characteristics of the subbase material used in this Project, a test section 30 m (100 ft) long by 2.5 m (8 ft) wide was first placed and compacted. A series of measurements of in situ density and moisture content was made using a nuclear density gage, as additional water was added incrementally and the section was compacted further. This process was continued until a curve was obtained yielding optimum moisture content and maximum density. The minimum compaction requirement was then set at 98% of the maximum density value obtained in this manner.

The subbase was compacted using a single, smooth drum vibratory roller with a static weight of 3.6 tonnes (4 tons). To prevent the migration of fines into the overlying base layer, a bituminous prime coat (Item 408) was applied to the top of the compacted subbase at 1.8 L/m<sup>2</sup> (0.4 gal/yd<sup>2</sup>). This application rate, however, made the subbase so soft that 24 hours had to pass before work could continue on top of this layer. A lower rate of application may, therefore, be used during the construction of the westbound lanes.

A 100-mm (4-in.) pipe underdrain was installed through the subbase layer, as shown in the pavement cross-section of Fig. 1.3.

#### **3.1.4 Base Placement**

The base is of the "New Jersey" type, consisting of a single 100-mm (4-in.) lift of crushed, well-graded, free-draining aggregate. Pertinent specifications are those for aggregate bases (Item 304) provided in the ODOT Manual (1995b) and reproduced in Appendix A. The aggregate material used in this Project was spread with a paver in order to minimize segregation, and was compacted to the level specified by ODOT using a smooth drum roller without vibration. A procedure similar to that used for the subbase, involving the construction of a test section to determine maximum density and moisture content, was employed. A 100-mm (4-in.) shallow pipe underdrain utilizing filter fabric was installed through this layer. This detail is shown in Fig. 1.3.

#### **3.1.5 PCC Slab Placement**

The mix design for the PCC slab was developed by the contractor, and called for the following material quantities: 245 kg/m<sup>3</sup> (412 lb/yd<sup>3</sup>) of Type I cement, 82 kg/m<sup>3</sup> (138 lb/yd<sup>3</sup>) of blast furnace slag, 823 kg/m<sup>3</sup> (1386 lb/yd<sup>3</sup>) of river sand with a bulk specific gravity (BSG) of 2.61, and 789 kg/m<sup>3</sup> (1329 lb/yd<sup>3</sup>) of #8 gravel with a BSG of 2.57. The water/cement (w/c) ratio used was 0.438. The #8 gravel was used because the #57 gravel originally considered did not pass the freeze-thaw (F-T) test for this area. The slab was

placed using slipform construction in accordance with ODOT (1995b) specification 451.03, reproduced in Appendix A. The concrete mix was monitored at the paver, where necessary corrections were formulated and relayed back to the batch plant. It was generally necessary to add aggregate and sand to keep the mix at the desirable slump and consistency. Testing performed by ODOT technicians consisted of in situ slump tests and laboratory tests on beams cast in the field. The specified strength of these beams was a modulus of rupture of 4.2 MPa (600 psi), under a third-point loading test.

### **3.1.6 Joint Sawing**

Initial saw cutting took place several hours after the paving operations, as soon as the concrete had developed enough strength to support the Soff-Cut G2000 saw. The widening cut was made with a 65-HP Core Cut saw, typically one day before sealant installation.

### **3.1.7 Joint Cleaning**

Following joint widening, the joints were cleaned with pressurized water and air. Joints were first flushed clean with water at 14 MPa (2000 psi), then air-blasted at 0.7 MPa (100 psi), before being allowed to dry.

### **3.1.8 Backer Rod Installation**

The backer rod was installed into those cleaned joints that were to be sealed with silicone or hot-applied sealants, after such joints had been allowed to dry, typically

overnight. Backer rod sizes of 6, 8 and 13 mm (1/4, 5/16 and 1/2 in.) were used, depending on the joint configuration. Typically, the backer rod was 3 mm (1/8 in.) larger than the joint opening. The backer rod was laid out across the pavement surface and rolled into place using a special hand tool.

### **3.1.9 Joint Sealing**

Joint sealing took place after the joint had been cleaned and dried, and, if required, the backer rod had been installed. Air-blasting at 0.7 MPa (100 psi) was repeated immediately before sealing to remove any debris that could have accumulated since the first cleaning.

The silicone sealants were all placed under pressure using a joint sealant pump mounted to the back of a truck. The non-sag silicone sealants were tooled into place using a piece of rubber tubing.

The Delastic and Watson Bowman compression seals were installed using a motor-powered machine, which also applied an adhesive lubricant (ChemMasters 105) to the joint opening. When problems with the machine were encountered, however, hand installation was used, during which the workers coated the seal with the adhesive lubricant, and fed it into the joint opening.

Prior to installing the TechStar W-050 seal, the sides of the joint were coated with a TechStar adhesive. The seal was then folded and fed into the mouth of a hand installation tool that fed it into the joint. Figures from the product literature for this seal, reproduced in Appendix B, detail the TechStar installation procedure.

## **3.2 Construction Problems**

As a result of prevailing cold temperatures, it was sometimes found that the concrete had not set up uniformly through the concrete slab thickness by the time the original joint cut was made. This resulted in considerable joint spalling. It appeared that the concrete was setting from the bottom up, since the underside of the slab was warmer than its top, and some shrinkage cracks had been initiated prior to the initial cut. Subsequently, a lighter saw was used, which enabled the crew to make the cuts as specified. A number of short sections in which premature shrinkage cracks had formed prior to the first saw-cut, or in which excessive joint spalling developed were removed and replaced after the concrete had cured.

Wednesday

Our Neighbors

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opens parent-child dialogue

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to focus on intercultural awareness

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Features and events  
for senior citizens

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Weather

Thursday:  
Partly cloudy  
High 76/Low 53

Page 2

# The Athens Messenger

Wednesday, June 4, 1997

Vol. 92, No. 163

A daily part of your life

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35 Cents



— Messenger photo by John Halley  
**GROUND-BREAKING** — Landowners affected by the Route 50 widening project turn shovels of dirt Guyssville, and Nettie and Jerry Storer and Pete Tuesday at a ground-breaking ceremony. From left Couladis of Athens.

## Route 50 landowners take part in ceremonial ground-breaking

By TERESA SMITH  
 Messenger staff writer

Construction of the latest phase of the Route 50 widening "represents a commitment to this corridor and to the growth and development of Southeastern Ohio," according to Jerry Wray, director of the Ohio Department of Transportation.

Wray spoke at a ground-breaking ceremony held Tuesday at Dow Lake.

"Projects like this one bring with them a promise of economic development," Wray said.

Construction has started on a seven-mile stretch of Route 50 between Athens and Guyssville.

The project, the second of four phases to widen Route 50 to four lanes, will cost \$29 million and is the largest project ODOT's District

10 has taken on.

An official ground-breaking was held even though construction is already under way. People whose property is affected by the project participated in the ceremony.

Lt. Governor Nancy Hollister, a former mayor of Marietta, also attended.

"When you see those orange barrels and orange cones, that's progress," Hollister said. "This project is very important to me.... I drive this road at least once a week."

"The benefits of this project will be seen for generations to come," Hollister said.

Construction is expected to be completed in October 1998. The section from Coolville to Fought's Auto Sales should be completed this Au-

gust. The two remaining sections will be bid out over the next two years, and the entire project should be finished around 2001.

"We have spent a lot of long hours and a lot of work to get here," ODOT Deputy Director John Dowler said.

Construction engineer Paul Hoffmann said that ODOT will replace wetlands that must be eliminated by the construction, and the state is doing all it can to preserve the ecology of the area.

Dowler said that in addition to the seven miles of highway, four miles of frontage road also will be built along the corridor.

"We don't want to build a development road and leave the land unable to be developed," Dowler said.

Fig. 3.1 Local press coverage of new highway construction

## **4 PERFORMANCE OF TEST SECTIONS TO DATE**

### **4.1 General**

Joint sealant experiments require a rather lengthy evaluation period, sometimes exceeding ten years. Consequently, the evaluation presented herein is naturally limited. Performance evaluation to date includes a profilometer analysis of the pavement surface and a visual inspection of the test sections in the eastbound lanes.

### **4.2 Profilometer Analysis**

On June 10, 1998 a pavement surface profile reflecting the current condition of the test sections in the newly constructed eastbound lanes was recorded using ODOT's Inertial Profilometer, Model 690DNC. This test machine is capable of making profile measurements at speeds between 16 and 113 km/hr (10 and 70 mile/hr). The profile of the test sections was recorded in intervals of 16 m (0.01 mile). The profilometer produced results in terms of Mays Number (MAYS), Present Serviceability Index (PSI), left wheel-track International Roughness Index (IRI<sub>lf</sub>), right wheel-track International Roughness Index (IRI<sub>rt</sub>), and an average of both values of International Roughness Index (IRI<sub>bh</sub>). The print-out of the results, along with information on the profilometer equipment itself, is presented in Appendix C. In measuring the test section profile in the eastbound lanes, six

runs were made. Of these, three “up” runs (from west to east) were made beginning at the start (Sta 154+00) and terminating at the end of the test sections (290+00), along the outer (driving) lane. Three additional “down” runs were also made, in the opposite (east to west) direction, following the inner (passing) lane.

Table 4.1 presents the results of a statistical analysis of the profilometer data collected. These results reflect the initial condition of the roadway surface, and may be useful in providing a suitable basis for future comparisons.

### **4.3 Visual Inspection of Condition of Test Sections in Eastbound Lanes**

On October 29, 1998 the University of Cincinnati research team accompanied by Mr Lynn Evans, of *ERES Consultants, Inc.*, conducted a visual inspection of the condition of the test sections in the eastbound lanes, from Sta 154+00 to Sta 290+00. Since the pavement was under considerable traffic at the time, the inspection was conducted from the shoulder adjacent to the outer (driving) lane. The air temperature was 21°C (70°F) under partly cloudy weather conditions. The following observations were recorded.

#### **4.3.1 TechStar W-050 (Sta 154+00 to 160+00)**

This seal was generally in good condition, but exhibited a permanent bulge along its centerline due to summer joint width reduction. At the approach and leave of this bulge, some cohesive distress was noted, along with occasional adhesion failure. It was estimated that 1 to 3% of the total joint length had either adhesion or cohesion failure.

The sealant appeared to be recessed from the pavement surface about 3 mm (1/8 in.), avoiding significant exposure to traffic.

#### **4.3.2 No Seal (Sta 160+00 to 166+00)**

These unsealed joints appeared to be in good condition. On the pavement shoulder, small stones and debris filled the transverse joints to the top, while in the traffic lanes, these stones and debris were typically recessed 25 to 50 mm (1 to 2 in.). It was noted that grass was beginning to grow in the traffic lane joints at some locations. The actual joint width appeared to be greater than the design width.

#### **4.3.3 Dow 890-SL (Sta 166+00 to 172+00)**

Typical recess for the sealant in this section was 0 to 3 mm (1/8 in.), with 5% of the seal length estimated to be exposed to direct tire traffic. This had led to adhesion failure in an estimated 1% of the joint length. In one joint, the backer rod appeared to have been installed incorrectly, resulting in sunken sealant and the appearance of cohesion failure.

#### **4.3.4 Crafc 444 (Sta 172+00 to 188+00)**

This jet fuel resistant, hot applied sealant appeared to be soft and resilient. Joint sealant recess typically ranged from 3 to 6 mm (1/8 to 1/4 in.). Evident in the sealant surface were small bubbles, commonly created during sealant installation; their frequency was about 1 to 5 bubbles per cm (2 to 10 bubbles per in.). It was estimated that 20 to

25% of the joint length had developed partial-depth adhesion loss, and that full depth adhesion failure occurred in 5 to 10% of the joint length.

#### **4.3.5 Crafc 903-SL (Sta 188+00 to 194+00)**

The sealant in this section was typically recessed 3 to 6 mm (1/8 to 1/4 in.) below the pavement surface, except within 75 to 150 mm (3 to 6 in.) from the shoulder edge, where it was exposed to traffic. The sealant was in good condition with less than about 2% adhesion distress or failure, with the exception of one joint which exhibited about 20% adhesion failure.

#### **4.3.6 Watson Bowman WB-687 (Sta 194+00 to 200+00)**

No problems were observed with the seal in this section. The seal was typically recessed 6 to 10 mm (1/4 to 1/2 in.), avoiding traffic tire contact. The presence of excess lubricant/adhesive on the pavement surface reflects the fact that the seal was placed by hand.

#### **4.3.7 Crafc 902 (Sta 200+00 to 206+00)**

This non-sag silicone sealant appeared to be in good condition and exhibited no problems during this review. The sealant was typically recessed 3 to 6 mm (1/8 to 1/4 in.), slightly less than optimal, but showed no signs of adhesion problems.

#### **4.3.8 Crafcro 903-SL (Sta 206+00 to 213+00)**

The condition of these seals was rather poor, suggesting a number of construction problems. Many of them were inadequately recessed, showing signs of wear due to exposure to traffic along about 90% of the joint length. About 80% of the joint length had already developed partial-depth adhesion loss, and about 5 to 10% of the length exhibited full-depth adhesion failure. It appears likely that the recommended procedures of installing the sealant up from the bottom of the joint to avoid trapping air bubbles in the joint and of maintaining adequate recess were not followed with adequate stringency. The nozzle used may have been too wide to allow its insertion into the joint during sealant delivery, resulting in overfilled joints.

#### **4.3.9 Dow 890-SL (Sta 213+00 to 219+00)**

Insufficient recess was also a large problem with this section. It was estimated that about 90% of the seal length was exposed to traffic wear, resulting in partial-depth adhesion loss along about 5 to 10% of the joint length.

#### **4.3.10 No Seal (Sta 219+00 to 225+00)**

No problems were noted in this section. These joints were originally cut using a Soff-Cut sawing system, with no additional cut made. The shallow, narrow joints resulting from this procedure may serve to reduce stone and debris infiltration and improve the performance of these joints.

#### **4.3.11 Delastic V-687 (Sta 225+00 to 231+00)**

The compression seal in this section was noted to be in very good condition. Adequate sealant recess, 6 to 9 mm (1/4 to 3/8 in.), was observed and the seal remained tight and untwisted against the joint walls. Adhesive lubricant stains on the pavement surface reflect the fact that these seals were installed by hand.

#### **4.3.12 Crafc0 221 (Sta 260+00 to 266+00)**

Like the Crafc0 444, this hot-applied sealant was found to be soft and resilient at the prevailing temperature; bubbles were evident in the sealant surface, possibly reflecting low amounts of sealant in the melter-applicator or moist joint surfaces at the time of installation. The sealant was noted to be recessed approximately 3 mm (1/8 in.), and partial-depth adhesion loss was estimated along 5% of the joint length. Full-depth adhesion failure was estimated along 1% of the joint length.

#### **4.3.13 Dow 890-SL (Sta 266+00 to 272+00)**

The sealant in this section was performing well, despite the fact that it was inadequately recessed, at 0 to 3 mm (1/8 in.). It was noted that approximately 40% of the seal surface was exposed to traffic wear, yet only about 1% of adhesion loss seemed to have developed. Ordinarily, exposed seals are expected to develop significant adhesion failure.

#### **4.3.14 Dow 888 (Sta 272+00 to 290+00)**

Good performance was noted for the silicone sealant in this section. Joint sealant recess of about 6 mm (1/4 in.) was observed and only 1 to 2% partial- and full-depth adhesion loss was estimated.

**Table 4.1** Statistical analysis of the profilometer data

Avg runs 1,2,3 up					
	MAYS	PSI	IRIif	IRIrt	IRIbh
AVG	45.48	4.298	52.03	66.72	59.37
MAX	104.3	4.596	134.9	119.1	124.5
MIN	22.97	3.859	15.33	35.4	31.5
STD	14.04	0.143	20.99	15.57	14.89
COV%	30.88	3.326	40.35	23.33	25.08

a) Average of the values for all three passes in the driving lane (start to end)

Avg runs 1,2,3, down					
	MAYS	PSI	IRIif	IRIrt	IRIbh
AVG	52.63	4.169	56.4	85.18	70.79
MAX	116.1	4.578	144.7	174.6	147.5
MIN	19.83	3.188	18.37	36.37	29.23
STD	15.7	0.194	23.26	21.48	18.29
COV%	29.84	4.658	41.25	25.22	25.83

b) Average of the values for all three passes in the passing lane (end to start)

Averages by sealant section for all 6 runs:						
		Mays	PSI	IRIif	IRIrt	IRIbh
Sta154-160	TechStar W-050	41.87	4.221	40.81	68.79	54.8
Sta 160-166	No Sealant	42.69	4.216	38.45	72.47	55.47
Sta 166-172	Dow 890-SL	51.62	4.241	56.87	75.51	66.19
Sta 172-188	Crafco 444	48.45	4.259	53.83	73.57	63.7
Sta 188-194	Crafco 903-SL	44.08	4.323	57.72	68.25	62.99
Sta 194-200	WB-687	51.5	4.188	54.51	80.08	67.29
Sta 200-206	Crafco 34903-SL	52.21	4.157	55.2	84.06	69.63
Sta 206-213	Crafco 903-SL	43.01	4.394	56.41	62	59.21
Sta 213-219	Dow 890-SL	43.87	4.237	50.92	66.79	58.85
Sta 219-225	No Sealant	45.92	4.307	56.92	67.67	62.29
Sta 225-231	Delastic V-687	43.3	4.325	50.58	65.52	58.04
Sta 260-266	Crafco 221	61	4.134	65.28	91.28	78.27
Sta 266-272	Dow 890-SL	47.6	4.183	44.13	80.95	62.54
Sta 272-284	Dow 888	46.55	4.299	50.65	70.61	60.63
Sta 284-290	Dow 888	47.3	4.23	47.63	72.76	60.2

c) Averages for each test section for all six passes

## 5 SUMMARY

This research experiment is conducted to gain a better understanding of the role of joint sealing in newly-constructed concrete pavements. This report documents the first phase of the construction operations conducted during the 1997-98 season, involving the eastbound lanes of US Route 50 near Athens, OH. *Kokosing Construction Company, Inc.* is responsible for the performance of all operations relevant to this experiment, including subgrade preparation; subbase, base and PCC slab placement; and joint cutting, joint cleaning, and sealant installation.

Nine joint sealants and six joint configurations are used. Two unsealed control sections are also included. Of the nine sealants used, four are silicone sealants, two are hot-applied sealants, and three are compression seals. Performance evaluation to date is limited. A profile of the pavement surface recorded shortly after the newly constructed lanes were opened to traffic (June 1998) is expected to provide a useful baseline for future pavement condition comparisons. A visual evaluation of the sealant performance to date was also conducted (October 1998).

## 6 REFERENCES

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Voigt, G. F. (1997), "Summary of State Highway Agency Use of Joint Sealant for Transverse Contraction Joints in Highway Pavements," Proceedings, Pavement Crack and Joint Sealants for Rigid and Flexible Pavements Conference, Vicksburg, MS, May 20-21, pp. 70-86.

## **APPENDIX A**

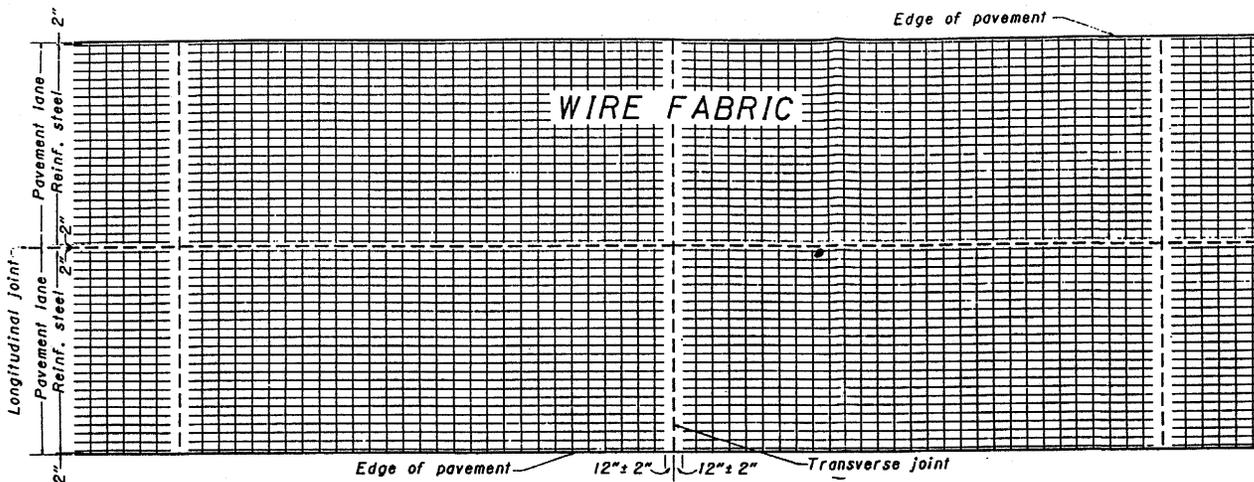
### **Test Site Construction Specifications**

☛ **ODOT Standard Construction Drawings (ODOT, 1994)**

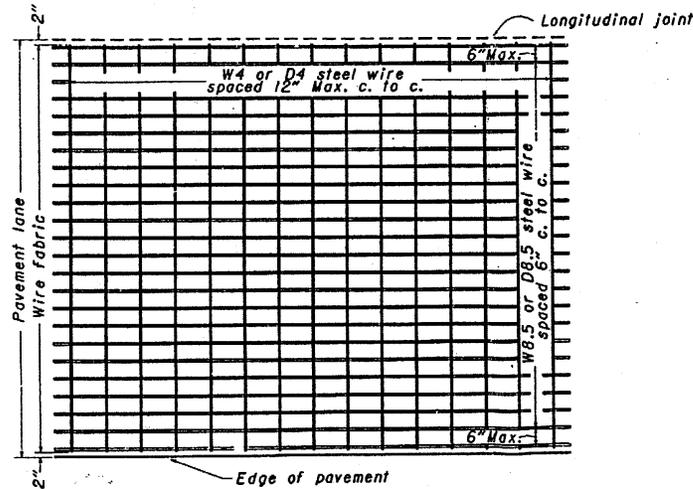
☛ **ODOT Construction and Material Specifications (ODOT, 1995b)**



# STANDARD CONSTRUCTIONS DRAWINGS



PLAN



WIRE FABRIC DETAIL

NOTES

STEEL REINFORCING in normal or wider lane widths may consist of two units with an approved longitudinal hinge. The hinge shall consist of W4 or D4 steel wires connecting the two units such that the longitudinal members on either side of the hinge will be properly spaced when the reinforcing is in final position. The distance from the top of the concrete pavement to the reinforcing steel may vary from  $\frac{1}{2}$  inches to  $\frac{1}{3} \times 1$  inch, where 1 = thickness of the concrete pavement.

BUREAU OF LOCATION AND DESIGN OHIO DEPARTMENT OF TRANSPORTATION		DATE 2-2-32
<b>CONCRETE PAVEMENT REINFORCING</b>		
STANDARD CONSTRUCTION DRAWING	<b>BP-1.1</b>	
APPROVED	B.K. N...	ENGR., L & D

**NOTES**

**GENERAL:** Longitudinal joints shall be used when called for on the typical section and shall be constructed as shown on this drawing in 451 and 452 pavement and 305 base. The joint shall be on the centerline of the pavement unless otherwise shown. Each round deformed bar, a satisfactory device shall be used to hold the tie bars in proper position or they may be installed by a mechanical installing device.

**BUTT JOINT:** The longitudinal joint between adjoining slabs poured in separate operations shall be a butt joint with hook bolts or tie bars, unless otherwise shown on plans. Bent tie bar construction shall not be permitted.

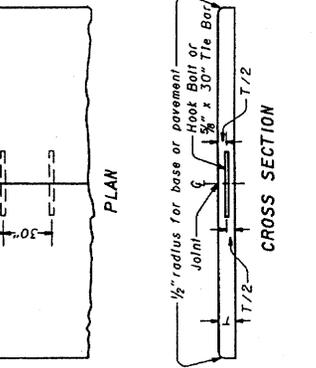
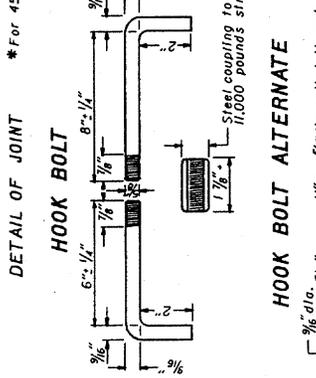
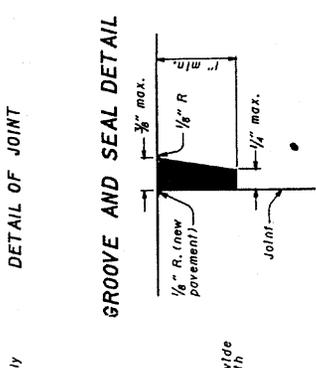
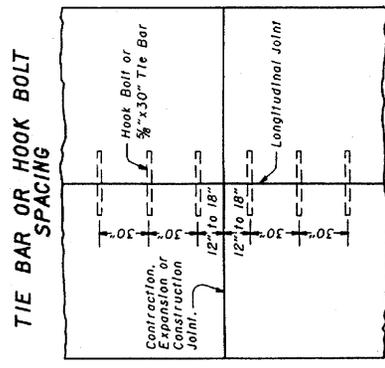
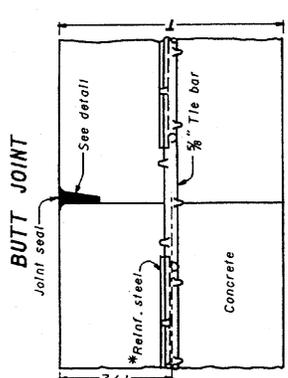
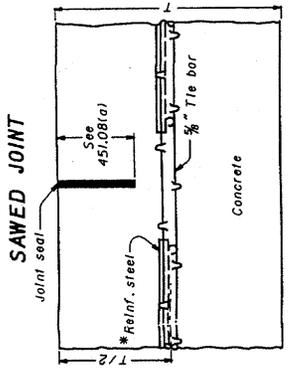
**TYPE D (DRILLED TIED LONGITUDINAL JOINT):** Type D joints shall meet the requirements of 255.02. The use of expansion anchors FF-S-325, Group VIII, Type I or Group II, Type 4, Class I may be used in lieu of the \*5 x 24" deformed bar, and shall be installed according to the manufacturer's recommendations.

**GROOVES:** Grooves for sealing expansion bolt or butt joints in 451 or 452 pavements shall be formed by impressing a device or bar into the freshly poured concrete. The device or bar shall be removed as soon as the concrete is in such condition as to preclude distortion of the concrete. Adjoining slabs adjacent to grooved joints shall be edged with a thin metal edger having a radius of 1/8" inch. Any impression left in the slab shall be eliminated.

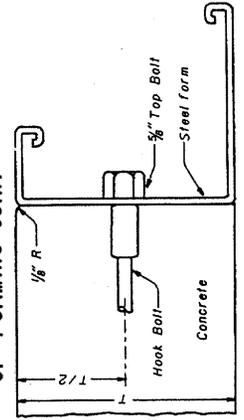
**SEALING JOINTS:** Sowed or hand-formed joints may be sealed with 705.04 or 705.11 joint sealer. Sealing of longitudinal joint in item 305 base is not required.

**HOOK BOLTS:** Hook bolt inserts shall be turned to a tight fit when installed in threaded hook bolts or couplings.

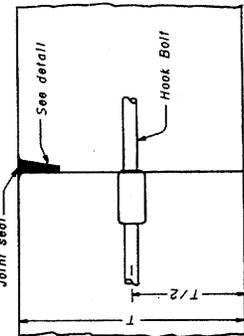
**METAL STRENGTH:** Tie bars, hook bolt assemblies and hook bolt alternate shall have a minimum strength of 11,000 pounds.



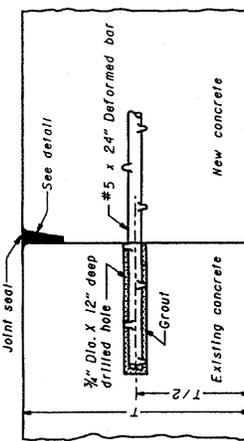
**ACCEPTABLE METHOD OF FORMING JOINT**



**BUTT JOINT**



**TYPE D (DRILLED TIED LONGITUDINAL JOINT)**



BUREAU OF LOCATION AND DESIGN  
OHIO DEPARTMENT OF TRANSPORTATION

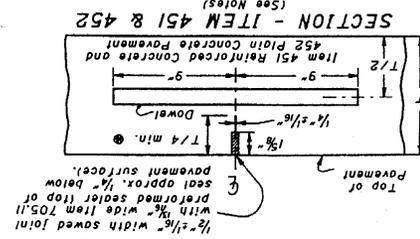
**LONGITUDINAL PAVEMENT JOINTS**

DATE: 2-29-82  
10-28-84

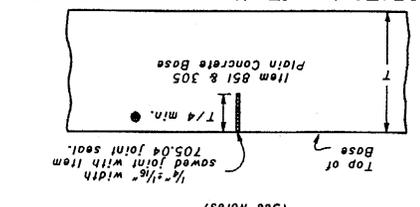
STANDARD CONSTRUCTION DRAWING: **BP-2.1**

APPROVED: *S.K. HULL* CIVIL ENGR., L.S.D.

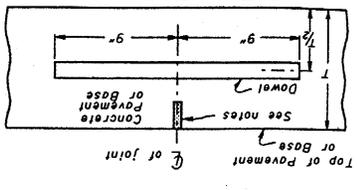
**CONTRACTION JOINTS**



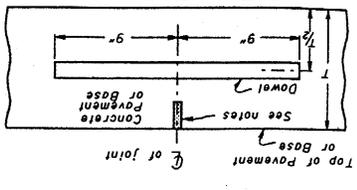
**SECTION - ITEM 451 & 452**



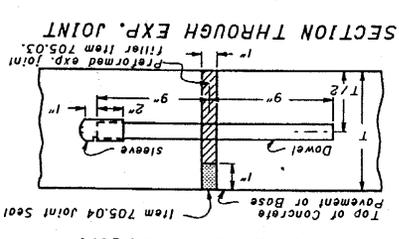
**SECTION - ITEM 851 & 305 BASE**



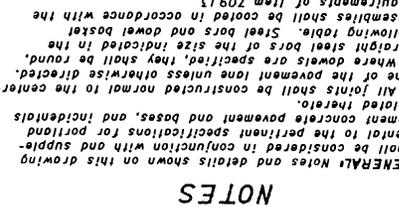
**SECTION THROUGH CONSTRUCTION JOINT**



**EXPANSION JOINT**



**SECTION THROUGH EXP. JOINT**



**NOTES**

GENERAL Notes and details shown on this drawing shall be considered in conjunction with and supplemental to the pertinent specifications for portland cement concrete pavement and bases, and incidental related thereto.

All joints shall be constructed normal to the center line of the pavement unless otherwise directed. Where dowels are specified, they shall be round, straight steel bars of the size indicated in the following table. Steel bars and dowel baskets assemblies shall be coated in accordance with the requirements of Item 709.13.

Dowels shall be spaced at 12" centers. Where  $T > 10"$ , the sawcut depth shall be  $T/3$ .

**CONSTRUCTION JOINT**

ASSEMBLY: Each joint assembly used to hold dowels in position shall be continuous between longitudinal joints or between longitudinal joint and pavement edge. The assembly shall be firmly held in proper position by at least eight  $1/2"$  steel pins driven at an angle to brace the assembly from lateral and vertical displacement during the placing of the concrete. These pins shall be at least 18" in length. Two of these pins shall be placed in the pavement, ramps, acceleration/deceleration lanes, or collector/distributor lanes, or CONTRACTION JOINTS: All contraction joints in Item 451 Reinforced Concrete Pavement shall be dowelled. Contraction joints in Item 452 Plain Concrete Pavement shall be dowelled where they are located in machine paving, ramps, acceleration/deceleration lanes, or collector/distributor lanes, or

**EXPANSION JOINTS:** Expansion joint filler shall be held rigidly in position and shall be continuous for the full width of each lane. The face of the expansion joint shall be perpendicular to the concrete surface and shall not be staggered horizontally except when abutting a staggered bridge approach slab. Smooth dowel shall be used, and free movement shall be provided by applying a coating of a thin layer of oil or other "bond-breaking" material just prior to placing the concrete. One free end of each dowel shall be equipped, after coating, with a sleeve or metal or other approved material approximately 3" long, designed with crimped end and overlapping seams fitting closely around the dowel. Each sleeve shall be provided with a depression or interior projection to act as a stop for the dowel, sufficiently distant from the crimped end to allow 1" for longitudinal dowel movement with pavement expansion. In lieu of this requirement, any other means may be used if approved by the Director. Proper size dowel holes shall be punched or drilled into the preformed expansion joint filler in order to insure tight fitting dowels.

**CONTRACTION JOINTS:** All contraction joints in Item 451 Reinforced Concrete Pavement shall be dowelled. Contraction joints in Item 452 Plain Concrete Pavement shall be dowelled where they are located in machine paving, ramps, acceleration/deceleration lanes, or collector/distributor lanes, or

DOWEL SIZE (T) THICKNESS DIAMETER OF PAVEMENT	STEEL DOWEL	shown on plan
over 10"	1"	over 10"
8.6" to 10"	1 1/2"	1 1/2" or as shown on plan
8.5" or less	1"	1"

be driven opposite each other of each end of the assembly and the remaining pins shall be driven in staggered positions on each side of the assembly. In exceptional cases where it is impractical to use the 18" length pins, such as where hoodpin or rock is encountered, the Engineer may authorize use of shorter pins provided the assembly is held firmly, where the assembly is placed on greater material which may allow settlement or distortion. The assembly shall be anchored to prevent settlement or distortion of the assembly with some combination of pins and/or steel plates, or by some other means to the satisfaction of the Engineer.

When concrete pavement is placed on an existing concrete pavement or a stabilized base, the joint assemblies (baskets) shall be held firmly in position by the use of a power driven fastener and an appropriate clip, or 6 locations along the basket from lateral and city, or 6 locations along the basket from lateral and vertical displacement during concrete placement.

Dowel spacing is shown for pavement lanes of even foot widths. Where other widths are specified, adjusted as follows:

The 6" dowel spacing shall be maintained at the longitudinal joint. The spacing of the dowel shall be increased up to 12" where an odd width of lane occurs, a dowel shall be placed 6" from the outer edge of the lane if the standard cage would provide for a space exceeding 12". Such a dowel shall be held rigidly in proper position by a method satisfactory to the Engineer or a dowel cage of greater length than required may be used by cutting the assembly and splicing to obtain the required length.

This drawing is intended for use with a uniform depth pavement. When the project involves the placing of a partial depth pavement, the joint components shall be held in place in accordance with the method shown in the plan or as approved by the Engineer.

Expansion joint filler shall be continuous for the full width of each lane. The face of the expansion joint shall be perpendicular to the concrete surface and shall not be staggered horizontally except when abutting a staggered bridge approach slab. Smooth dowel shall be used, and free movement shall be provided by applying a coating of a thin layer of oil or other "bond-breaking" material just prior to placing the concrete. One free end of each dowel shall be equipped, after coating, with a sleeve or metal or other approved material approximately 3" long, designed with crimped end and overlapping seams fitting closely around the dowel. Each sleeve shall be provided with a depression or interior projection to act as a stop for the dowel, sufficiently distant from the crimped end to allow 1" for longitudinal dowel movement with pavement expansion. In lieu of this requirement, any other means may be used if approved by the Director. Proper size dowel holes shall be punched or drilled into the preformed expansion joint filler in order to insure tight fitting dowels.

**CONTRACTION JOINT SPACING**

TYPES OF PAVEMENT OR BASE	MAXIMUM SPACING BETWEEN JOINTS
Item 451 Reinforced Concrete Pavement	21 lin. ft.
Item 452 Plain Concrete Pavement	17 lin. ft.
Items 851 & 305 Plain Concrete Base	20 lin. ft.

\* Where Item 452 Plain Concrete Pavement (for Concrete Base

shoulders, etc.) is being placed and tied longitudinally to Item 451 Reinforced Concrete Pavement, or Item 305, Plain Concrete Base, the joints in Item 452 shall match the spacing alignment, sawing, and sealing requirements of the joints in Item 451 or 305. Where Item 452 Plain Concrete Pavement, its being used as a shoulder, rumble strips shall be placed as per Std. Constr. Dwg. B-P-B.1. CONTRACTION JOINTS: Smooth dowels shall be used in transverse construction joints in all portions of cement concrete pavements, shoulders and bases. The joint shall be formed by using an adequate butthead that will provide a straight joint. The butthead shall have openings provided for dowel bars spaced as outlined under "GENERAL". The butthead shall be shaped to fit the typical section of the pavement or base. Dowels shall be held rigidly in position during the placing of the concrete. Construction joints in reinforced concrete or cement concrete pavement may be located at a contraction joint or between contraction joints, provided they are not closer than 10 feet to another parallel joint. In plain concrete pavement or concrete base a contraction joint shall not be located closer than 6 feet to another parallel joint. Key and seal construction joint in concrete details shown for contraction joints shall be provided for each construction joint in concrete sealing base contraction joints. All contraction joints for plain concrete bases shall be sealed as detailed herein and the cost included in the unit price bid for Item 305 or 851.

**TRANSVERSE PAVEMENT JOINTS**

OHIO DEPARTMENT OF TRANSPORTATION  
BUREAU OF LOCATION AND DESIGN  
DATE 2-21-92  
10-28-94

STANDARD DRAWING  
CONSTRUCTION BP-2.2  
ENGR. L & D

**STATE OF OHIO**

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**DEPARTMENT OF  
TRANSPORTATION  
COLUMBUS, OHIO**

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**CONSTRUCTION AND MATERIAL  
SPECIFICATIONS**



**JANUARY 1, 1995**

**An Equal Opportunity Employer**

subgrade and to a width of 0.46 m (18 inches) beyond the edge of the surface of the pavement, paved median, paved shoulder, or to the back of the adjacent curb and gutter, and shall be paid for as a separate item under 203 Subgrade Compaction.

Subgrade under pavement widening less than 1.8 m (6 feet), driveways, mailbox turnouts, and stabilized shoulders, shall be compacted to a depth of 150 mm (6 inches) below the surface of the subgrade and to the width of the pavement or base, or to the back of adjacent curb and gutter; and shall not be paid for as a separate item. The cost of compacting subgrade to a depth of 150 mm (6 inches) shall be included in the unit price bid for 203 Excavation.

Where the combined width of pavement widening and adjacent paved shoulder is 1.8 m (6 feet) or more, the subgrade shall be compacted as under new pavement and shall be paid for as a separate item under 203 Subgrade Compaction. For method of measurement, see 203.15(f).

(b) **Drainage.** The surface of the subgrade shall be maintained in a smooth condition to prevent ponding of water after rains, and ditches shall be constructed and maintained in accordance with 203.04 (a) Drainage, to insure the thorough drainage of the subgrade surface at all times.

(c) **Soft Subgrade.** Where soft subgrade is encountered in cuts, due to no fault or neglect of the Contractor, in which satisfactory stability cannot be obtained by moisture control and compaction as provided for under 203.11 and 203.13 (a), the unstable material shall be excavated to the depth required by the Engineer. The excavation thus required shall be measured and paid for at the contract unit price bid for 203 Excavation. Material thus excavated shall be disposed of in accordance with 203.05.

Where embankment is a separate pay item, material required to replace the undercut shall be provided from 203 excavation, if available from grading operations within 1 km (½ mile) of the soft subgrade area. Suitable material shall be considered available when within 1 km (½ mile) of the soft subgrade area only when there is an excess of suitable material on the entire project, available portions of which are located within 1 km (½ mile) of the soft subgrade area. Embankment required in the undercut area shall be paid for at the contract unit price for 203 Embankment, except that if such material is not available, the excavation thus made shall be filled with any suitable material available beyond 1 km (½ mile) of the soft subgrade area, and payment shall be made in accordance with Section 104.03.

Where embankment is not a separate pay item, suitable material required for the embankment to replace the undercut shall be secured from 203 Excavation if available from grading operations

203.12 **Embankment Compaction.** Soil embankment shall be placed and compacted in layers until the density is not less than the percentage of maximum dry density indicated in the following table determined by AASHTO T 99 or other approved method.

**EMBANKMENT SOIL COMPACTION REQUIREMENTS**

Maximum Laboratory Dry Weight Kilograms/Cubic Meter (Pounds/Cubic Foot)	Minimum Compaction Requirements	
	Percent Laboratory Maximum	
1440-1680 (90-104.9)	102	
1681-1920 (105-119.9)	100	
1921 and more (120 and more)	98	

203.13 **Subgrade.** All soil subgrade shall be prepared in accordance with this subsection. Soils with a maximum dry weight of less than 1600 kg/m<sup>3</sup> (100 pounds per cubic foot) are considered unsuitable for use where subgrade compaction for a depth of 0.30 m (12 inches) is required, and when encountered in the upper 0.30 m (12 inches) of the subgrade shall be replaced with suitable soil or granular material.

(a) **Compaction Requirements.** Soil subgrade with maximum laboratory dry weight of 1600-1680 kg/m<sup>3</sup> (100-105 pounds per cubic foot) shall be compacted to not less than 102 per cent of maximum dry density. All other soil subgrade shall be compacted to not less than 100 percent of maximum dry density. The maximum dry density shall be as determined by AASHTO T-99 or other approved method.

Subgrade under new pavement and paved shoulders shall be compacted to a depth of 0.30 m (12 inches) below the surface of the

within 1 km (½ mile) of the soft subgrade area. If such suitable material is not available, the excavation thus made shall be filled with suitable material from 203 Borrow or with any suitable material available beyond 1 km (½ mile) of the soft subgrade area in accordance with Section 104.03.

Where soft subgrade in cuts is due to the failure of the Contractor to maintain adequate surface drainage as required in 203.04 (a) Drainage, or is due to any other fault or neglect of the Contractor, the unstable condition shall be corrected as outlined above at no expense to the State.

**(d) Full Width New Pavement Construction.** After the surface of the subgrade has been shaped to approximate cross section grade, and before any pavement, base or subbase material is placed thereon, the subgrade and a portion of the berm for a distance of at least 0.5 m (18 inches) outside the limits of the surface of the planned pavement, shall be compacted. When the rolling is completed, the surface of the subgrade shall be shaped as necessary to conform to the grade and cross section shown on the plans within the tolerance set forth in 203.06 and shall be so maintained until the overlying course is in place.

**203.14 Proof Rolling.** Proof rolling shall be performed on areas described on the plans or as directed by the Engineer.

**(a) Equipment.** The equipment shall consist of four heavy pneumatic tire wheels mounted on a rigid steel frame. The wheels shall be evenly spaced in one line across the width of the roller and shall be arranged so that all wheels will carry approximately equal loads when operated over an uneven surface. The maximum center to center spacing between adjacent wheels shall not exceed 0.8 m (32 inches). The compacting equipment shall have a suitable body for ballast loading with such capacity that the gross load may be varied from 23 to 45 metric tons (25 to 50 tons).

The tires shall be capable of operating at inflation pressures ranging from 620 to 1040 kPa (90 to 150 pounds per square inch). From 90 to 95 percent of the volume of the tires shall be filled with liquid. The Contractor shall furnish the Engineer charts or tabulations showing the contact areas and contact pressures for the full range of tire inflation pressures and for the full range of loading for the particular tires furnished.

Ballast to obtain the weight directed by the Engineer shall consist of ingots of known unit weight, or sand bags with a unit weight of 45 kg (100 pounds) or bags of other material of known unit weight, or other suitable material such that the total weight of the ballast used can be readily determined at all times. There shall be a sufficient amount of ballast available to load the equipment to a maximum gross weight of 45 metric tons (50 tons).

**(b) Construction.** The designated areas of subgrade, prior to the placing of the overlying course, shall be compacted to requirements of 203.13. The subgrade shall then be rolled with one or more coverages, as directed, of the heavy pneumatic tire roller. One coverage shall be considered to represent two trips of the roller, each trip offset from the other by the width of one tire, to obtain complete area coverage. The roller shall operate in a systematic manner so that the number of coverages over all areas can be readily determined and recorded.

Moisture content of the subgrade at the time of proof rolling shall conform to the requirements of 203.11.

Within the ranges set forth above, the load and tire inflation pressure shall be adjusted as directed. It is the intent to use a contact pressure as nearly as practical to the maximum supporting value of the subgrade. The equipment shall be operated at the speed directed but in no case shall the speed exceed 8 km per hour (5 miles per hour), and the normal operating speed shall not be less than 4 km per hour (2½ miles per hour).

Where the operation of the heavy pneumatic tire roller shows the subgrade to be unstable or to have non-uniform stability, the Contractor shall correct the unstable areas in accordance with the provisions of 203.13 so that the stability of the subgrade will be uniform and satisfactory. The subgrade shall then be checked for conformance to the plan lines and any irregularities of the surface caused by operation of the heavy pneumatic tire roller shall be corrected and the subgrade shall be shaped to the plan lines within the tolerance specified in 203.06.

Proof rolling will not be required where rock or shale occurs in subgrade, or in areas where subbase has been thickened to replace frost susceptible silts or other unsuitable subgrade material.

Aggregate acceptance shall be determined prior to incorporation into the work based on samples taken from stock piles.

Prior to placing, aggregate shall have a reasonably uniform moisture content at or near optimum for compaction.

**304.03 Placing.** When vibratory equipment is used in conjunction with other methods of compaction, the compacted depth of a single layer shall not exceed 150 mm (6 inches). When vibratory compaction equipment is not used, the maximum compacted thickness of one layer shall not exceed 75 mm (3 inches). When the required compacted depth of the base course exceeds 150 mm (6 inches), the base shall be constructed in two or more layers of approximately equal thickness.

The aggregate shall be placed with self-propelled spreading machines capable of placing the aggregate true to line and grade. Approved hand placing methods may be used when the total area of base course is 1700 m<sup>2</sup> (2,000 square yards) or less, or in small areas where machine spreading is impractical. In these areas the compaction requirement shall be in accordance with 203.12.

Unless the base course is placed in a trench section, the edges shall be backed up with an 0.5 m (18 inch) width of soil, placed to such a height that it will be consolidated to the height of the lift being compacted and furnish positive lateral support during compaction of the course.

Adequate surface drainage of the berm shall be provided at all times.

**304.04 Compaction.** At the beginning of the compaction operation, the density requirement shall be determined by compacting a short section, at the direction of the Engineer, until no further increase in density is obtained. The remainder of the course shall be compacted to a density not less than 98 percent of the test density. A new density requirement may be determined when the aggregate characteristics change appreciably. The surface of each layer shall be maintained during the compaction operations in such a manner that a uniform texture is produced and the aggregates firmly keyed. Water shall be uniformly applied over the base materials during compaction in the amount necessary to maintain the moisture at or near optimum.

The finished surface shall not vary more than 10 mm (3/8 inch) from a 3.0 m (10 foot) straightedge parallel to the centerline nor more than 13 mm (1/2 inch) from a template conforming to the required cross section. The Contractor shall furnish straightedges, templates or other devices satisfactory to the Engineer and check the surface for conformance with these requirements.

**ITEM 304 AGGREGATE BASE**

- 304.01 Description
- 304.02 Aggregate
- 304.03 Placing
- 304.04 Compaction
- 304.05 Method of Measurement
- 304.06 Basis of Payment

**304.01 Description.** This work shall consist of furnishing, placing and compacting one or more courses of aggregate, including furnishing and incorporating all water required for compacting, on a prepared surface in accordance with these specifications, and in reasonably close conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

**304.02 Aggregate.** The aggregate shall be crushed carbonate stone, crushed gravel, crushed air-cooled slag, granulated slag, a mixture of crushed and granulated slags, or other types of suitable materials meeting the requirements of this item and having the approval of the Director. Crushed carbonate stone, crushed gravel, crushed air-cooled slag or mixtures of crushed and granulated slags shall meet the following gradation requirements and the requirements of 703.04. In addition, open-hearth and basic-oxygen furnace slags shall conform to the stockpiling and aging requirements of 703.01.

Sieve	Total Percent Passing
50 mm (2 inch)	100
25.0 mm (1 inch)	70-100
19.0 mm (3/4 inch)	50-90
4.75 mm (No. 4)	30-60
600 μm (No. 30)	9-33
75 μm (No. 200)	0-13

Granulated slag shall also meet the requirements of 703.08, sec. 1.

**450 RIGID PAVEMENT**  
**ITEM 451 REINFORCED PORTLAND CEMENT**  
**CONCRETE PAVEMENT**

451.01	Description
451.02	Materials
451.03	Equipment
451.04	Setting Forms
451.05	Finegrading of Subgrade or Subbase
451.06	Placing Concrete
451.07	Placing Reinforcement
451.08	Joints
451.09	Finishing
451.10	Curing
451.11	Removing Forms
451.12	Surface Smoothness
451.121	Profile Grinding
451.122	Pavement Grooving
451.13	Sealing Joints
451.14	Opening to Traffic
451.16	Pavement Thickness
451.17	Method of Measurement
451.18	Basis of Payment

**451.01 Description.** This work shall consist of a pavement composed of reinforced portland cement concrete constructed on a prepared subgrade or base course in accordance with these specifications and in reasonably close conformity with the lines, grades, thickness and typical cross sections shown on the plans or established by the Engineer.

**451.02 Material.** Material shall be:

Concrete .....	499 Class C
Joint sealer .....	705.04
Preformed elastomeric joint sealer .....	705.11
Preformed filler .....	705.03
Curing materials .....	705.05, 705.06, 705.07 (Type 2)
Reinforcing steel .....	709.09, 709.10, 709.12
Tiebar steel .....	709.00
Dowel bars and basket assemblies .....	709.13
Expansion shield anchors .....	712.01 Type A

**451.03 Equipment.** Machines for finishing concrete pavement shall be mechanical, self-propelled spreading and finishing machines, and shall be capable of consolidating and finishing the con-

crete and which produces a finished surface meeting the requirements herein specified.

At the option of the Contractor, pavement shall be constructed with equipment utilizing stationary side forms or by the use of slip form paving equipment. Equipment shall conform to the following:

a) Form Construction. Concrete shall be uniformly spread, screeded and consolidated by one or more machines between previously set side forms. The number and capacity of machines furnished shall be adequate to perform the work required at a rate equal to that of the concrete delivery. These machines shall uniformly distribute and consolidate the concrete without segregation.

Vibration for the full width of paving shall be accomplished by internal vibrators operating at 7000 to 11,000 impulses per minute. Vibrators may be attached to either the spreading or finishing equipment. They shall not come in contact with preset load transfer devices, the subgrade, or the side forms. Power to vibrators shall be connected so that vibrators cease when the machine's motion is stopped. The Contractor shall have available for the Engineer's use a tachometer, or other frequency measuring device, capable of verifying the frequency.

Machines shall be capable of operating either on side forms or on adjacent lanes of pavement. When concrete is being placed adjacent to an existing pavement, protective measures shall be taken to protect the adjacent pavement from damage. Any machine which causes displacement of the side forms from the line or grade or causes undue delay due to mechanical difficulties shall be removed from the work.

Small or irregular areas which are inaccessible to finishing equipment may be finished with other methods as approved by the Engineer. Vibration of these areas shall be accomplished by hand held or machine mounted internal vibrators. Vibrating shall be done to achieve adequate consolidation for the full depth and width of the area placed, without segregation.

Side forms shall be of steel, straight, and of a depth equal to the thickness of the pavement at the edge, except forms of greater depth than specified pavement thickness may be used by written permission of the Director. Any additional cost caused by the use of forms of a greater depth shall be included in the bid price for this item. The use of bent or damaged side forms or forms with damaged joint locks or pin pockets shall not be permitted. All forms shall be cleaned and oiled each time they are used. They shall be furnished in sections not less than 3.0 m (10 feet) in length, with horizontal joint and base width equal to the depth of the forms. Flexible or curved forms shall be of a design acceptable to the

Engineer and shall be used for construction of circular pavement edges where the radius is 30 m (100 feet) or less. Forms shall be provided with adequate devices for secure setting so that when in place they will withstand the operation of the paving equipment. Built-up forms shall not be used except where the total area of pavement of any specified thickness on the project is less than 1650 m<sup>2</sup> (2,000 square yards). The forms shall contain adequate joint locks for joining the ends of abutting form sections together tightly.

b) Slip Form Construction. The concrete shall be placed with a slipform paver or combination of pavers designed to spread, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finish will be necessary to provide a dense and homogeneous pavement. The machine shall vibrate the concrete for the full width and depth of the strip of pavement being placed. Vibration shall be accomplished by internal vibrators attached to the pavers and operating at 7000 to 11,000 impulses per minute. Vibrators shall not come in contact with load transfer devices or the subgrade. The Contractor shall have available to the Engineer a tachometer or frequency measuring device to verify frequency.

The concrete shall be maintained at a uniform consistency, having a slump of not more than 75 mm (3 inches). The slipform paver shall be operated with as nearly a continuous forward movement as possible and all operations of mixing, delivering, and spreading concrete shall be coordinated as to provide uniform progress with stopping and starting of the paver held to a minimum. If for any reason, it is necessary to stop the forward movement of the paver, the vibrator and tamping elements shall also be stopped immediately. No tractive force shall be applied to the machine, except that which is controlled from the machine.

The finish grade of the pavement shall be accurately controlled from a grade line pre-set parallel to the finish grade. Slip form paving equipment shall have controls that will trace the grade line and automatically adjust the grade of the screeds or extension meters.

In areas where adjoining concrete pavement is to be constructed, the edge of the pavement on either side of the longitudinal joint shall not vary more than 6 mm (¼ inch) below the typical section. The outside edges of the pavement shall not vary more than 13 mm (½ inch) below the typical section.

In the area of construction joints placed at the end of the days run, a reduction of approximately 50 mm (2 inches) in overall width will be permitted.

**451.04 Setting Forms.** All forms shall be set with reasonable conformance to the required grade and alignment and be sup-

ported on thoroughly compacted material for their entire length during the entire operation of placing and finishing of the concrete. After the setting of side forms the top face of the form shall not vary from a true plane more than 3 mm in 3.0 m (1/8 inch in 10 feet), and the vertical face shall not vary more than 6 mm in 3.0 m (1/4 inch in 10 feet), and they shall be tested by the Contractor and variations from the above requirements shall be eliminated by resetting the forms. Shimming with loose earth, pebbles, etc., will not be permitted. The alignment and grade of all forms set shall be approved before and immediately prior to the placing of concrete.

**451.05 Finegrading of Subgrade or Subbase.** (a) Form Construction. After side forms have been set to line and grade and securely fastened, the subgrade or subbase shall be brought to final grade by means of a subgrader or subgrade planer. This finegrading operation should involve a slight removal of the subbase material and bring the subbase to a smooth dense condition. The subgrade or subbase shall be checked using a multiple pin template operated on the forms or other methods approved by the Engineer. Any high or low spots found shall be corrected and rechecked.

In lieu of the above operation, forms may be placed on the subbase or subgrade which has been prepared as specified in 451.05(b).

b) Slip Form Construction. After the subbase or subgrade has been placed and compacted to the required density, the areas on which the pavement is to be constructed and the areas which will support the paving machine shall be cut to the plan elevation by means of a automatic subgrading machine. If the density of the base is disturbed by the grading operations, it shall be corrected by additional compaction before concrete is placed. The grade shall be constructed sufficiently in advance of placing the concrete to permit checking. If any traffic is allowed to use the prepared grade, the grade shall be checked and corrected immediately ahead of placing of the concrete. If satisfactory stability of the subbase material cannot be obtained, it shall be stabilized by addition of admixes or angular aggregate particles at no increase in cost.

**451.06 Placing Concrete.** The subgrade or subbase shall be sprinkled at such times and in such manner as directed by the Engineer so that it will be in a thoroughly moistened condition when the concrete is deposited thereon.

The concrete shall have a slump in accordance with 499.03 and shall be deposited on the grade in a manner that requires as little rehandling as possible. Workmen shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with earth or foreign material.

Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them, but shall not be dumped from the discharge bucket or hopper onto a joint assembly unless hopper is well centered on the assembly. Concrete shall be consolidated around expansion and construction joints by means of internal vibration.

Sawing equipment necessary to saw joints is permitted to operate on the newly constructed pavement provided damage to curing membrane is repaired to the satisfaction of the Engineer. Other mechanical equipment shall not be operated upon existing lane of pavement until that lane has been in place for at least seven days or until specimen beams shall have attained a modulus of rupture of 4.2 MPa (600 psi). If only finishing equipment is carried on the existing lane, paving may be permitted after that lane shall have been in place for at least three days or after specimen beams shall have attained a modulus of rupture of 3.5 MPa (500 psi).

An approved spreader will be required when the width of pavement being placed in one operation is 3.6 m (12 feet) or more and the total area of any given width of the project exceeds 8300 m<sup>2</sup> (10,000 square yards).

No concrete shall be mixed, placed, or finished after dark, unless an adequate and approved artificial lighting system is operated.

For concrete placed when the temperature of the air is 2° C (35° F) or below, the concrete immediately after placing in the forms, shall have a temperature of between 10 and 27° C (50 and 80° F).

The subgrade or subbase upon which concrete is to be placed shall be entirely free from frost, when concrete is deposited.

Concrete test specimens. Two test beams will be made from each 6300 m<sup>2</sup> (7,500 square yards) or fraction thereof, that is incorporated in the work each day.

**451.07 Placing Reinforcement.** When reinforced concrete pavement is placed in two layers, the entire width of the bottom layer shall be struck off to such length and depth that the mat of reinforcement may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed as specified directly upon the concrete, after which the top layer of concrete shall be placed, struck off and screeded. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or it may be placed in the plastic concrete, after spreading, by mechanical or vibratory means.

The mats of reinforcement forming each lap, in addition to being overlapped as specified shall be securely fastened together at the

edges of the sheets and at two additional points along the lap.

Reinforcing steel shall be free from dirt, oil, paint and grease.

**451.08 Joints.** Joints shall be constructed of the type, dimensions, and at locations specified.

(a) Longitudinal Joint. The longitudinal joint shall be constructed by sawing or by forming.

If the longitudinal joint between simultaneously placed lanes is made with a concrete saw, the sawing shall be done to a minimum depth of one-fourth of the specified pavement thickness for pavement less than or equal to 255 mm (10 inches) thick, and one-third of the specified thickness for pavements greater than 255 mm (10 inches) thick, within three days after the pavement is placed. The width shall be approximately 3 mm ( $\frac{1}{8}$  inch).

If the longitudinal joint between separately placed lanes is made with a concrete saw, the sawing shall be done to a depth of 13 mm ( $\frac{1}{2}$  inch). The width shall be approximately 6 mm ( $\frac{1}{4}$  inch).

If the longitudinal joint is formed, the groove for sealing shall be formed in the lane placed last.

Hook bolts when used, shall be securely fastened to the form of the longitudinal construction joint.

Expansion bolt joints shall be constructed by installing expansion shield anchors in the center of the existing pavement slab in accordance with the manufacturer's recommendation after which hook bolts shall be threaded firmly into the expansion shield anchors.

(b) Load Transfer Devices. Dowels shall be held in position parallel to the surface and centerline of the slab by an approved metal device that is left in the pavement. Dowels may be placed in the full thickness of pavement by a mechanical device approved by the Engineer. Deformed steel tiebars, when used for longitudinal joints, shall be placed by approved mechanical equipment or rigidly secured by chairs or other approved supports to prevent displacement. All wires shall be removed from dowel basket assemblies prior to paving. The dowel basket assemblies shall be stable and held firmly in place throughout the paving operations.

(c) Expansion Joints. Transverse expansion joints shall be provided on each approach to a bridge, or bridge approach slab at distances of approximately 6 m (20 feet) and 18 m (60 feet) or as specified. If the pavement is constructed in two or more separately placed lanes, the joints shall form a continuous line for the full width of the pavement.

An opening 25 mm (1 inch) in width by 25 mm (1 inch) in depth shall be formed for installation of 705.04 joint sealer.

(d) Contraction Joint. Contraction joints shall be sawed as specified to a minimum depth of one-fourth of the specified pavement thickness and a width of 6 mm  $\pm 1.6$  mm ( $\frac{1}{4}$  inch  $\pm \frac{1}{16}$  inch) determined at the time of sawing. If the pavement is constructed in two or more separately poured lanes, the joints shall be continuous for the full width of the pavement. Sawing shall be done with sawing equipment approved by the Engineer. Joints shall be sawed as soon as the saw can be operated without damaging the concrete. Saws shall be equipped with adequate guides, blade guards, and a method of controlling the depth of cut. Sawing may be done wet or dry but the joint must be cleaned by a jet of water or air under pressure after having been sawed. A standby saw in working condition with an adequate supply of blades shall be maintained at the site of the work during the sawing of contraction joints.

(e) Construction Joints. Construction joints shall be built as specified at the end of each day's work and whenever necessary to suspend the work for a period of more than 30 minutes. In no case shall an emergency construction joint be placed closer than 3.0 m (10 feet) to a parallel joint.

**451.09 Finishing.** The surface shall be continuously checked for trueness with 3.0 m (10 foot) straightedges. If the pavement surface is dragged with a diagonal pipe float machine, only occasional straightedge surface checks, while the concrete is plastic, will be required.

Before the concrete has taken its initial set, the edges of the pavement along each side of each slab, and on each side of transverse expansion joints, shall be worked with an approved tool and rounded to the radius specified. Any toolmarks left by the edging shall be eliminated by texturing the surface.

The surface shall be textured by use of a broom or artificial turf drag in the longitudinal direction so as to produce a uniform, gritty, longitudinal texture. In addition to and immediately following the above specified longitudinal drag texture, the pavement shall be textured in the transverse direction by an approved device that will produce a relatively uniform pattern of grooves. The grooves shall be spaced at approximately 16 mm ( $\frac{5}{8}$ -inch) centers and shall be approximately 4 mm (0.15 inches) deep and 3 mm (0.10 inches) wide. Variation from the texturing requirements will be permitted only with the written permission of the Director.

Station numbers shall be impressed into the pavement before it takes its final set. The complete station number is to be marked each 50 m (100 feet), e.g. 2+050. Where station equations occur they shall be marked in the pavement in the same manner as they are shown on the plans. The numerals shall be 75 to 100 mm (3 to

4 inches) in height and 6 mm (¼ inch) in depth. The station numbers shall be placed parallel with the pavement edge, and centered at 0.30 m (12 inches) in from and facing the right edge of the pavement. On divided highways, station numbers shall be provided on both pavements. When concrete shoulders are placed with the traveled lane, station numbers shall be placed 0.30 m (12 inches) in from the outside edge of the shoulder and facing the pavement.

**451.10 Curing.** Immediately after the finishing operations have been completed and after the free water has disappeared, all exposed surfaces of the concrete shall be sealed by spraying thereon a uniform application of curing membrane in such a manner as to provide a continuous uniform film without marring the surface of the concrete. The material shall be applied with an approved self-propelled mechanical sprayer. Wind protection to the spray fog shall be provided by an adequate shield. A minimum of 1 L (1 gallon) of material shall be used for each 3.7 m<sup>2</sup> (150 square feet) of surface treated. Curing material shall be thoroughly agitated immediately prior to use.

On pavement with integral curb or small and irregular areas which are inaccessible to the mechanical spray machine, the curing material may be applied by a hand spray.

As soon as the forms have been removed, any honey-comb areas shall be immediately corrected and the edges of the pavement coated with the curing material. Any areas of pavement film that may have been damaged during the sawing shall be resprayed during this operation.

Curing may also be accomplished by means of water curing with burlap cloth, waterproof paper or polyethylene sheeting.

Curing shall be applied as soon after the finishing operations as possible without marring the surface of the concrete.

The entire surface of the top and sides of the newly placed concrete shall be covered and maintained covered for seven days, unless specimen beams have attained a modulus of rupture of 4.2 MPa (600 psi).

The Contractor shall be responsible for protecting the concrete from freezing until beams attain a strength of 4.2 MPa (600 psi).

The above requirements for curing are minimum requirements only. Any concrete showing injury or damage due to inadequate curing shall be repaired or replaced by the Contractor at not additional cost.

**451.11 Removing Forms.** Forms shall be removed in such a manner that no damage will occur to the pavement. After the forms

have been removed, the sides of the slab shall be cured as outlined in 451.10.

**451.12 Surface Smoothness.** After the final curing of the concrete, the surface shall be cleaned and tested for smoothness by means of a surface testing machine which will test one or more lines on each side of the pavement as determined by the Engineer. All surface variations so indicated shall be corrected to within the specified tolerance in a manner that will provide the required texture specified in 451.09. Pavement surface variations, except as hereinafter stated, shall not exceed 3 mm (¼ inch) in a 3.0 m (10 foot) length of pavement. For ramp pavements and for those pavements with curvature greater than 8 degrees, or with grades exceeding 6 percent, the surface variation shall not exceed 6 mm (¼ inch) in 3.0 m (10 feet).

All surface variations which are found to be out of tolerance shall be corrected in a manner that will provide the required texture specified in 451.09. Equipment for corrective grinding or for restoration of transverse grooves shall comply with the requirements of 451.121 or 451.122.

Sections of pavement containing depressions which cannot be corrected by grinding shall be repaired or replaced by the Contractor to the satisfaction of the Engineer.

**451.121 Profile Grinding.** Equipment used to correct surface variations which exceed the tolerances specified in 451.12 shall be power driven, self propelled machines specifically designed to correct the profile and provide proper cross-slope on concrete pavement. The equipment shall use diamond impregnated blades or diamond impregnated cylinder rings. The blades or cylinder rings shall be mounted on an arbor head. The grinding head shall be a minimum of 0.9 m (3 feet) wide. The equipment shall be capable of grinding the surface in the longitudinal direction without causing damage to pavement joints. Bush hammers or other impact devices shall not be used.

**451.122 Pavement Grooving.** Equipment used for restoring transverse grooves in areas which are corrected to meet smoothness tolerances or other areas which do not have texture conforming to the requirements of 451.09 shall be power driven, self propelled machines specifically designed to groove concrete pavement with diamond impregnated blades or diamond impregnated cylinder rings. The blades or cylinder rings shall be mounted on an arbor head so that the resulting grooves comply with 451.09. The grooving equipment shall have a depth control device which will

detect variations in the pavement surface and enable adjustment of the cutting head to maintain the depth of the groove specified. The depth of the grooves on pavements which have been ground to meet smoothness tolerances of 451.12 shall be approximately 4 mm (0.15 inches) below the bottom of the ground section grooves. For small areas, variations from these requirements will be permitted only with the written permission from the Director.

**451.13 Sealing Joints.** Joints shall be sealed before the pavement is opened to traffic or to use by construction equipment, and as soon after completion of the sawing as is feasible. Just prior to sealing, each joint shall be thoroughly cleaned of all foreign material, using approved equipment, and the joint faces shall be clean and surface dry when the seal is applied.

Transverse contraction joints shall be sealed with preformed polychloroprene compression seals meeting the requirements of 705.11. Expansion joints shall be sealed with material conforming to 705.04 or 705.11. The seals shall be installed by suitable tools using an approved lubricant-adhesive which shall cover both sides of the sealer. The seals shall be installed in a substantially full compressed condition and shall at all times be below the level of the pavement surface by approximately 6 mm (¼ inch). The seals shall be in one piece without field or factory splice between longitudinal joint and edge of pavement or between longitudinal joints of multilane pavement. The elongation of the seals during installation shall not exceed 5 percent as determined by length measurement marks.

Formed joints shall be sealed with joint filler conforming to 705.04. Sawed joints shall be sealed with joint filler conforming to 705.04 or 705.11. The joint sealer shall be placed with proper equipment to obtain a neat workmanlike joint free from excess and unsightly filler.

**451.14 Opening to Traffic.** The completed pavement may be used for traffic, including construction traffic, when 7 days have elapsed. Provided that a modulus of rupture of 4.2 MPa (600 psi) has been attained, the pavement may be opened to traffic when 5 days have elapsed. In the event it is necessary to open a portion of the pavement in less than 5 days, high early strength concrete in accordance with 499.03 shall be used. The portion of pavement may be opened after 3 days provided test beams attain a modulus of rupture of 4.2 MPa (600 psi).

**451.16 Pavement Thickness.** Thickness of concrete at any point, determined by the measurement of cores cut as hereinafter specified, shall not be more than 13 mm (½ inch) less than the specified thickness, nor shall the average thickness of the concrete,

determined as hereinafter specified, be more than 5 mm (0.2 inch) less than the specified thickness. The length of the cores will be determined in accordance with AASHTO T 148.

The entire pavement shall be considered a unit for the purpose of coring.

One core shall be taken at random for every 1650 m<sup>2</sup> (2,000 square yards) of pavement or major fraction thereof, however, a minimum of three cores shall be taken from any pavement cored. Should any core show a deficiency in thickness of more than 13 mm (½ inch), additional cores shall be cut 1.5 m (5 feet), measured longitudinally, on each side of the location of the core deficient in thickness. If both these additional cores are within the 13 mm (½ inch) tolerance, special borings shall be continued 15 m (50 feet) and 30 m (100 feet), measured longitudinally from the location of the first core found to be deficient in thickness and thence at 30 m (100-foot) intervals longitudinally, until pavement thickness within the 13 mm (½ inch) tolerance is found in both directions or the end of the pavement is reached, thus establishing the longitudinal boundaries of the zone of deficiency, but in no case shall additional cores be cut longitudinally beyond the location of any boring in that lane at which the pavement thickness has been found to be within the 13 mm (½ inch) tolerance.

Where the separately poured width of pavement consists of two or more traffic lanes and a scheduled core shows a deficiency of more than 13 mm (½ inch), an additional core or cores shall be cut to determine the extent of the zone of deficiency in a direction transverse to the center line. The additional core or cores shall be cut approximately in the center of the traffic lane or lanes. Where a transverse core or cores are within the 13 mm (½ inch) tolerance, the zone of deficiency shall be limited to the traffic lane or lanes found to have deficient thickness. However, where any of the transverse core or cores is outside the 13 mm (½ inch) tolerance, the zone of deficiency shall include all traffic lanes where such deficiency was found and the longitudinal boundaries for each deficient lane shall be determined as above.

When any core shows a deficiency of more than 13 mm (½ inch), the area of the pavement for which payment shall be withheld, shall be the sum of the areas found to be deficient as determined above. Deductions will be determined and applied to each separately poured width of pavement.

All thickness measurements which are more than 13 mm (½ inch) greater than the specified thickness shall be regarded as the specified thickness plus 13 mm (½ inch).

The average thickness of concrete pavement shall be the mean thickness, in millimeters (inches), of the cores taken from the pave-

ment with the provision that whenever a total deduction occurs, the mean thickness of the two cores limiting the zone of deficiency longitudinally shall be used in lieu of the original core (in the zone) in the average thickness calculation. The other cores within a zone of deficiency shall be disregarded in this calculation.

Any widening less than 1.5 m (5 feet) in width or any pavement of less than 1650 m<sup>2</sup> (2,000 square yards) in area shall not be cored unless requested by the Director.

All core holes shall be filled by the Contractor with concrete of the same proportions and materials used in the pavement.

**Price Adjustments.** Where the average thickness of pavement is deficient in thickness by more than 5 mm (0.2 inch), but not more than 13 mm (0.5 inch), payment will be made at an adjusted price as specified in the following table:

#### Concrete Pavement Deficiency

Deficiency in Thickness as Determined by Cores.	Proportional Part of Contract Price
0.0 to 5 mm (0.0 to 0.2 inch)	100 percent
6 to 13 mm (0.3 to 0.5 inch)	Average thickness <sup>2</sup> [ Specified thickness ]
Greater than 13 mm (0.5 inch)	None

When the thickness of pavement is deficient by more than 13 mm (½ inch) and the judgment of the Engineer is that the area of such deficiency should not be removed and replaced, there will be no payment for the area retained.

**451.17 Method of Measurement.** The area under this item will be the number of square meters (square yards) of concrete pavement completed and accepted in place. The width of measurements will be the width of the pavement shown on the typical cross section of the plans, additional widening where called for, or as otherwise directed in writing by the Engineer. The length will be measured horizontally along the center line of each roadway or ramp. The plan quantities as adjusted for changes, errors and deviation in excess of allowable tolerances will be the method of measurement.

**451.18 Basis of Payment.** The accepted quantities of concrete pavement will be paid for at the contract unit price per square meter (square yard), which price and payment shall be full compensation for furnishing and placing all materials including reinforcing steel, dowels and joint materials; provided, however, that

for pavement found deficient in thickness only the reduced price stipulated in 451.16 shall be paid.

No additional payment over the unit contract bid price will be made for any pavement which has an average thickness in excess of that shown on the plans.

Payment will be made under:

Item	Unit	Description
451	Square meter (square yard)	Reinforced concrete pavement

## 705 CONCRETE PAVEMENT INCIDENTALS

**705.02 Silicone Joint Sealant.** 1. General. The sealant shall be furnished in a one part silicone formulation which does not require a primer for bond to concrete. The sealant shall be applied with a pressure applicator that forces it into the joint.

The backer rod shall be expanded, closed cell polyethylene foam. The backer rod shall be approximately 25 percent larger in diameter than the width of the joint or crack to be sealed. Other back-up materials (paper, rope and open cell foam) are unacceptable. The backer rod shall be compatible with the sealant, and no bond or reaction shall occur between the backer rod and sealant.

2. Silicone Sealant Requirements. The silicone sealant shall meet the requirements of the following Table:

Properties	Requirements
Flow, Supplement 1050	7.6 mm (0.3 inches) maximum
Extrusion Rate, Supplement 1050	75-350 grams/minute
Tack free time @ 25° C ± 2° C (77 ± 3° F), Supplement 1050	20-90 minutes
Specific Gravity; ASTM D 792, Method A	1.010-1.515
Durometer Hardness; Shore A, cured 7 days @ 25° C ± 2° C (77 ± 3° F) and 45-55% R.H.; ASTM D 2240	10-25 at -18° C (0° F)
Tensile Stress; @ 150% elongation, 7 day cure @ 25° C ± 2° C (77 ± 3° F) and 45-55% R.H.; ASTM D 412, Die C.	310 kPa (45 psi) maximum
Elongation; 7 day cure @ 25° C ± 2° C (77 ± 3° F) and 45-55% R.H.; ASTM D 412, Die C.	800% minimum
Bond to Concrete Mortar: Briquets; Air cured 12 days @ 25° C ± 2° C (77 ± 3° F);**	345 kPa (50 psi) minimum
Movement Capability and Adhesion ***	Extend 100% and compress 50%; No adhesive or cohesive failure after 10 cycles at -18° C (0° F)
Shelf Life	9 months from date of shipment from manufacturer

\*\*Bond to Concrete Mortar: Briquets molded in accordance with AASHTO T 132 sawed in half and bonded with a thin section of sealant and tested in accordance with AASHTO T 132. Briquets shall be dried to constant weight in oven at 100 plus or minus 5° C.

\*\*\*Movement Capability and Adhesion: Prepare 25 mm x 50 mm x 75 mm (1-inch x 2-inch x 3-inch) concrete blocks in accordance with ASTM C 719. A sawed face shall be used for bond surface. Seal 50 mm (2 inches) of block leaving 13 mm (½ inch) on each end of specimen unsealed. The depth of sealant shall be 10 mm (¾ inch) and the width 13 mm (½ inch). Subject sealant to movement in accordance with ASTM C 719. The magnitude of the movement shall be as specified, and the rate of extension or compression shall be 3.2 mm (¼ inch) per hour.

3. Approvals. All materials shall be prequalified by the Laboratory.

The manufacturer of the joint sealant shall furnish a letter of compliance for each lot of the joint sealer material furnished to the project. Each lot shall show the date of shipment from the manufacturer and shall be delivered in containers plainly marked with the manufacturer's name or trademark, and lot number. Material shall not be used after 9 months from the date of shipment from the manufacturer. Joint sealant shall be delivered to the job at least 2 weeks prior to the intended use.

Foam backer rod will be accepted by a letter of compliance.

**705.03 Preformed Fillers.** AASHTO M 153 or AASHTO M 213 with the following exceptions and additions:

3.7 Asphalt Content. The producer shall certify to the Engineer that the asphalt cement content is at least 35 percent by weight of the filler.

Inspection shall be done at the project site. Random samples shall be obtained from material delivered to the project site or at other locations designated by the Laboratory.

**705.04 Hot-Applied Crack and Joint Sealer.** ASTM D 3405.

**705.11 Preformed Elastomeric Compression Joint Seal for Concrete.** AASHTO M 220 with the following exceptions and additions:

5.1 Size and design shall be as shown on the plans.

7.2 Inspection shall be done at the project site. Random samples shall be obtained from material delivered to the project site, or at other locations designated by the Laboratory.

7.3 A minimum of 1.0 m (3 linear feet), with all manufacturers' markings, shall constitute one sample.

8.3 Specimens for the low temperature recovery tests shall be lightly dusted with talc on the outside surfaces only.

11.1 In addition 305 mm (1 foot) length markings shall be not less than 300 mm (11<sup>5</sup>/<sub>16</sub>) nor more than 310 mm (12<sup>1</sup>/<sub>4</sub> inches) from center to center.

The lubricants for installation of preformed compression seals shall be as recommended by the seal manufacturer.

Qualification. Each design, shape, width, depth, web and shell thickness, shall be approved by the Department prior to use. Drawings of the seals showing all dimensions and dimension tolerances and weight per meter (foot) shall be submitted with the request for design approval. A copy of Certified Test Data covering the specified properties of preformed elastomeric joint seals shall accompany the request for approval. 1.0 m (3 foot) length of elastomeric joint sealer shall be submitted concurrently with the request for qualification.

## **APPENDIX B**

### **Joint Sealant Product Literature**

☞ **Crafc 444**

☞ **Crafc 221**

☞ **Crafc 902**

☞ **Crafc 903-SL**

☞ **Dow 888**

☞ **Dow 890-SL**

☞ **Delastic V-687**

☞ **TechStar W-050**

☞ **Watson Bowman WB-687 and WB-812**



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PRODUCT DATA SHEET

**SUPERSEAL 444/777 SEALANT**

PART NO. 34651

JANUARY 1998

**READ BEFORE USING THIS PRODUCT**

**GENERAL** Crafco Superseal 444/777 sealant is a high quality, hot-applied fuel resistant sealant intended for use in sealing joints in portland cement concrete pavements in moderate to hot climates. The sealant is specifically formulated and produced to meet requirements of ASTM D3569-95 and D3406-95. Superseal 444/777 is supplied in liquid form in 5 gallon (19L) pails. Being initially liquid, Superseal 444/777 is much easier to handle during application than solid hot-poured sealant types. During application, Superseal 444/777 is simply poured into the melter applicator unit, heated to application temperature, and applied to prepared joints. At application temperature, Superseal 444/777 is self-leveling and produces uniform and neat sealed joints. After application and cooling, Superseal 444/777 forms a tough, resilient, well bonded seal for concrete pavement joints. Superseal 444/777 is formulated to be used only as a sealant for portland cement concrete pavements. It is not to be used in asphalt concrete pavements or extreme jet blast areas.

**SPECIFICATION CONFORMANCE** Crafco Superseal 444/777 meets all requirements of ASTM D3569, "Specification for Joint Sealant, Hot-Applied, Elastomeric Jet-Fuel Resistant Type, For Portland Cement Concrete Pavements" and ASTM D3406 "Joint Sealant, Hot-Applied Elastomeric Type, For Portland Cement Concrete Pavement".

<u>Test</u>	<u>ASTM D3569 and D3406 Spec. Limits</u>
Cone Penetration, 77F (25C)	1.30 cm max.
Fuel, Immersed Penetration (1)	Not greater than non-immersed pen
Flow, 158F (70C), 72 hrs.	No Flow
Bond, 0F (-18C), 50% ext.	No Separation, 3 cycles
Fuel Immersed Bond (1)	1/4" (.6cm) maximum separation, 3 cycles
Water Immersed Bond	No Separations, 3 cycles
Resilience, 77F (25C)	60% min.
Aged Resilience, 77F (25C)	60% min.
Artificial Weathering Test	Pass requirements
Tensile Adhesion	500% min.
Flexibility	Pass
Solubility	+/- 2.0% max.
Recommended Pour Temperature	270F (132C)
Safe Heating Temperature	290F (143C)

Note (1): Not required for D3406

**APPLICATION** The unit weight of Superseal 444/777 is 10.1 lbs/gal (1.21 kg/L) per gallon at 60F (15.5C). Prior to use, the user must read and follow Application Instructions for Hot Applied Superseal Sealants (December, 1997) to verify proper product selection, heating methods, pavement preparation procedures, application geometrics, usage precautions and safety procedures. These instructions are provided with each pallet of sealant.

**PACKAGING** The sealant is packaged in 5 gallon (19L) pails with 36, polyethylene lined, pails per pallet. Application Instructions are provided with each pallet in a weather resistant enclosure.

**WARRANTY** CRAFTCO, Inc. warrants that CRAFTCO sealants meet applicable ASTM, AASHTO, Federal or State specifications at time of shipment. Techniques used for the preparation of the cracks and joints prior to sealing are beyond our control as are the use and application of the sealants; therefore, Crafco shall not be responsible for improperly applied or misused sealants. Remedies against Crafco, Inc., as agreed to by Crafco, are limited to replacing nonconforming product or refund (full or partial) of purchase price from Crafco, Inc. All claims for breach of this warranty must be made within three (3) months of the date of use or twelve (12) months from the date of delivery by Crafco, Inc. whichever is earlier. There shall be no other warranties expressed or implied. For optimum performance, follow Crafco recommendations for sealant installation.



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**APPLICATION INSTRUCTIONS**

**HOT-APPLIED SUPERSEAL SEALANTS**

PART No's 34651, 34653, 34655, 34656

JANUARY 1998

44/77

**READ BEFORE USING THIS PRODUCT**

**GENERAL:** Crafco Superseal sealants are liquid, hot-applied, single component materials which when properly applied form resilient and adhesive compounds which effectively seal joints in portland cement concrete pavements. Since Superseal sealants contain coal tar, which is not compatible with asphalts, they should not be used to seal asphalt concrete cracks or joints or in places where they will be in contact with asphalt concrete pavement.

**HEATING:** Crafco Superseal sealants must be heated in jacketed double boiler type melter units equipped with both agitation and recirculation systems. During heating Superseal sealants will be thin up to temperatures of approximately 170°F (77°C). Between 170°F (77°C) and 200°F (93°C) the sealant will thicken considerably as constituents polymerize. As temperature increases above 240°F (116°C) the sealant will thin. When 250°F (121°C) is reached, the material circulation pump should be started. Sealant should be heated to between the recommended pouring temperature of 270°F (132°C) and the safe heating temperature of 290°F (143°C). Melter applicators with horizontal agitators should be powered by an engine of at least 16 HP and be equipped with an agitator in first class operating condition. If vertical agitators are used, the engine should have at least 12 HP. The melter applicator should also be equipped with a rotary pump with a 2 inch (5cm) minimum port size and without an internal pressure relief valve. The pumping system should include a 2 inch (5cm) manual bypass that will allow recirculation of the sealant from the pump back into the heating vat at the top of the tank. A 15 foot (5m) sealing hose with a 1 inch (2.5cm) inside diameter, coupled to a sealing wand with a 3/4 inch to 1 inch (1.9-2.5cm) inside diameter is ideal. Superseal sealants must be charged into a clean melter. All residue from previous sealants must be cleaned out of the entire system. This is accomplished by heating the melter to remelt residue and flushing the system with 10 gallons (38L) of Crafco Flush Oil (Part No. 34630). Superseal sealants may be charged into a clean melter as soon as the oil bath heaters and sealant agitator are operational. The entire amount of material may be added at once and the polyethylene liner may also be included. Do not completely fill machines with cold sealant because the material will expand approximately 10 percent when reaching application temperature. Important precautions during heating are as follows:

1. **AGITATION:** It is absolutely essential that continuous agitation of Superseal sealants be maintained when heat is being applied.
2. **TEMPERATURE CONTROL:** Temperature controls and indicators on the sealing machine must be maintained to a degree of accuracy than can be totally relied upon. An additional hand held temperature gauge should also be used to verify sealant temperature.
3. **SAFE HEATING TEMPERATURE:** Do not exceed the safe heating temperature. Temperatures in excess of the safe heating temperature reduce the pot life drastically and will cause gelling (curing to a solid). When this happens it is necessary to remove the sealant physically from the melter by cutting, scraping, etc. and disposed of properly. Superseal sealants may be remelted if allowed to cool and become solid, however they may not meet the intended specifications and should not be applied to pavement joints. At the safe heating temperature the application life of Superseal sealants is approximately nine hours.
4. **CIRCULATION:** Do not attempt to recirculate Superseal sealants at temperatures under 250°F (121°C)
5. **ADDITION OF FRESH MATERIAL:**  
One of the following two methods is recommended:  
A. Add full five gallon pail(s), the polyethylene bag liner may be included. A maximum amount of 10% fresh material should be added to the heated sealant. After addition, circulate material through plumbing and applicator wand back into the melter for a minimum of ten minutes after adding fresh material prior to restarting sealant application.  
B. Place fresh material into a tray mounted inside the melter lid opening. This tray should control the rate of fresh material addition to one-half gallon, (2L) or less, per minute. The polyethylene bag liner can be added to the melter when most of the fresh material has drained from it. It is not necessary to wait for material reaction when using this method.

Special care should be given to avoid plugging the machine when adding to less than fifty gallons of heated material. Do not apply material that is below the recommended application temperature.

**JOINT PREPARATION AND SEALANT APPLICATION:**

**New Concrete:** All joints should be formed or sawed to produce a minimum joint size of 3/8" x 1 1/2" (1.0 x 3.8 cm), on approximately 15 foot (5m) spacing. Joints 1/4 inch (1.2cm) wide should be 1 3/4 inch (4.4cm) deep and 5/8 (1.6cm) inch wide should be 1 7/8 inch (4.8cm) deep. Prior to sealing the joint, surfaces should be cleaned of all dirt, curing compound residue, laitance and any other foreign material. After sawing, immediately flush the joints with water to remove a majority of the saw slurry. After the joints has dried, just prior to applying sealant, the remaining residue must be removed by sandblasting "Both Joint faces must be adequately sandblasted to remove traces of sawing residue". For effective sandblasting the nozzle should be positioned within 2 inches (5cm) of the surface being cleaned. After sandblasting the joint should be cleaned using clean compressed air with a minimum pressure of 90 psi (62 N/cm<sup>2</sup>). Moisture and oil traps are required on compressor unit. The objective of the above cleaning operations is to provide vertical, intact and clean concrete bonding surfaces which are free

from all contaminants and are dry. Joints should be carefully inspected to assure that an appropriate level of cleanliness has been achieved. This can be accomplished by rubbing your finger along each joint face, if any evidence of dust and contaminants occur, additional sandblasting should be performed until all dust and contaminants are removed.

Non-water absorptive and heat resistant backer rod which is about 25% larger than the joint width should be placed in the joint to provide a minimum sealed depth of 3/4 inch (1.9cm). Do not puncture the backer rod. Damaged backer rod may cause sealant to bubble. Sealant should be applied at a temperature between the recommended pour temperature and the safe heating temperature. Sealant should be recessed a minimum 1/8 inch (3mm) below the pavement surface. Sealant should not be applied if ambient temperature or joint temperature is below 50°F (10°C) or in excess of 90°F (32°C). Bubbles are known to develop in hot-applied sealant which have been installed in concrete pavements. This phenomenon may develop within the first year of field service when hot summer temperatures occur. Bubbling is generally more noticeable in pavement less than one year old. Hot ambient temperatures can cause moisture in the concrete to vaporize. These moisture vapors will migrate through the sealant creating bubbles. An alternate sealant should be used if bubbling is not acceptable to the project owner. A low modulus non-sag silicone sealant will reduce the chance of bubble formation. Contact the Crafco Product Manager for further information.

**Resealing:** Old sealant should be removed by any appropriate method such as using a joint plow, a router, or hooks. After removal of old sealant, the joint is to be saw cut to an appropriate width to provide clean vertical bonding surfaces which are free from contamination by old sealant. As a general rule, the joint should be sawn to a width which is between 1/8 inch and 1/4 inch (3-6mm) wider than the original joint. The same joint depths listed in the "New Concrete" section should be used. For reservoir width of 3/4 inch (1.9cm), joint depth should be a minimum 1 7/8 inch (4.8cm). The additional sandblasting and cleaning operations contained in the above "New Concrete" section should then be followed.

**CLEAN OUT:** Superseal sealants should not be reheated and applied. Therefore, the sealing machine must be completely emptied at the end of the sealing run and the entire system flushed with Crafco Flush Oil. Ten gallons (38L) of flush oil should be used, circulating it through the bypass system as well as the sealing hose and wand. Once the system has been cleaned and emptied, the flush oil should be disposed of properly and not reused.

**SAFETY PRECAUTIONS:** All personnel involved with the sealing operation should read the Material Safety Data Sheet for Crafco Superseal sealants before sealing is started. User should check D.O.T. requirements for transportation of sealant at elevated temperatures (above 212°F).

**STORAGE:** Superseal sealants should not be stored in direct sunlight, and ambient storage temperature should not exceed 100°F (38°C). Do not store sealant outside under a tarp or plastic cover as this could lead to excessive heat buildup under the cover. Sealant should be stored inside with adequate ventilation.

**SAFETY AND USAGE PRECAUTIONS:** Since Superseal Sealants must be heated to elevated temperatures to prepare for use, it is essential that operations be conducted in manners which assure safety of the application personnel and other. All personnel associated with use of the material need to be aware of the hazards of using hot applied materials and safety precautions. Before use, the crew should read and understand all sections of the product Material Safety Data Sheet. This sheet which is supplied with each shipment, describes the characteristics of the product as well as any potential health hazards and precautions for safe handling and use.

**HAZARDS ASSOCIATED WITH HOT APPLIED MATERIALS:** Simply stated, skin contact with hot applied materials will cause burns. Additionally, over exposure to fumes may cause respiratory tract irritation, nausea, or headaches. Therefore, appropriate precautions need to be taken to prevent contact with the hot material, and to avoid inhalation of fumes for everyone in the vicinity of the sealing operation. Safety precautions should include: 1. protective clothing to prevent skin contact with hot material. 2. Care when adding product to melters to reduce splashing. 3. Careful operation and control of wands or our pots which are used to apply product. 4. Traffic and pedestrian control measures which meet or exceed local requirements to prevent access to work areas while product is still in a molten state. 5. Avoidance of material fumes. 6. Proper application configurations with a minimum amount of excesses of material. 7. Appropriate clean up of excessive applications or product spills.

**ADDITIONAL INFORMATION:** Additional information regarding these products is available by contacting your distributor or Crafco, Inc. This information includes 1) Product Data Sheets, 2) Material Safety Data Sheets, 3) Safety Manual, 4) Sealant Selection Guide.



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## PRODUCT DATA SHEET

# ROADSAVER 221 SEALANT

PART NO. 34221

JANUARY 1998

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### READ BEFORE USING THIS PRODUCT

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**GENERAL** CRAFCO RoadSaver 221 sealant is a single component, hot-applied petroleum based pavement crack and joint sealant which meets all requirements of ASTM D3405 and AASHTO M301. The sealant exceeds requirements of ASTM D1190, AASHTO M173 and Federal Specification SS-S-164. RoadSaver 221 is supplied in solid block form which is easily melted. When properly applied, RoadSaver 221 will form a long lasting resilient seal which is flexible and extensible at sub-zero temperatures and which resists tracking at summer temperatures. RoadSaver 221, can be applied to pavement cracks and joints using either pressure feed melter applicator units or pour pots. RoadSaver 221 is suited for sealing cracks and joints in both asphalt and portland cement concrete highway and airfield pavements in moderate to cooler climates.

**SPECIFICATION CONFORMANCE** Specification limits for RoadSaver 221 when tested for conformance with ASTM D3405 are:

<u>Test</u>	<u>ASTM D3405 Spec. Limits</u>
Cone Penetration	90 max.
Flow	3mm max.
Resilience	60% min.
Bond, -20F (-29C), 50% ext.	Pass 3 cycles
Asphalt Compatibility	Compatible
Recommend Pour Temperature	380F (193C)
Safe Heating Temperature	410F (210C)

**APPLICATION** The unit weight of Crafco RoadSaver 221 is 10.0 lbs. per gallon (1.20 kg/L) at 60F (15.5C). Prior to use, the user must read and follow Application Instructions for Hot Applied Asphalt Rubber, Asphalt Rubber Plus, Polyflex and RoadSaver Sealants (December 1997) to verify proper product selection, heating methods, pavement preparation procedures, application geometry, usage precautions and safety procedures. These instructions are provided with each pallet of sealant.

**PACKAGING** Packaging consists of individual boxes of sealant which are palletized into shipping units. Boxes contain a non-adherent film which permits easy removal of the sealant. Each pallet contains 72 boxes which are stacked in six layers of 12 boxes per layer. The weight of sealant in each box does not exceed 40 lbs. (18kg) and pallet weights do not exceed 2,880 lbs. (1310kg). Pallets of sealant are weighed and product is sold by the net weight of product. Sealant boxes are manufactured from double wall kraft board producing a minimum bursting test certification of 350 psi (241 N/cm<sup>2</sup>) and using water resistant adhesives. Boxes use tape closure and do not contain any staples. Boxes are labeled with the product name, part number, lot number, specification conformance, application temperatures and safety instructions. Palletized units are protected from the weather using a two mil thick plastic bag, a weather and moisture resistant cap sheet and a minimum of two layers of six month u.v. protected stretch wrap. Pallets are labeled with the product part number, lot number and net weight. Application instructions are provided with each pallet in a weather resistant enclosure.

**WARRANTY** CRAFCO, Inc. warrants that CRAFCO sealants meet applicable ASTM, AASHTO, Federal or State specifications at time of shipment. Techniques used for the preparation of the cracks and joints prior to sealing are beyond our control as are the use and application of the sealants; therefore, Crafco shall not be responsible for improperly applied or misused sealants. Remedies against Crafco, Inc., as agreed to by Crafco, are limited to replacing nonconforming product or refund (full or partial) of purchase price from Crafco, Inc. All claims for breach of this warranty must be made within three (3) months of the date of use or twelve (12) months from the date of delivery by Crafco, Inc. whichever is earlier. There shall be no other warranties expressed or implied. For optimum performance, follow Crafco recommendations for sealant installation.



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**APPLICATION INSTRUCTIONS**  
**Hot Applied Asphalt Rubber, Asphalt Rubber Plus,**  
**Polyflex and RoadSaver Sealants**

JANUARY 1998

**READ BEFORE USING THIS PRODUCT**

**GENERAL:** These application instructions pertain to the following Crafco Sealant Products.

**ASPHALT RUBBER SEALANTS:** 34232, 34233, 34234, 34235, 34236, 34237, 34239, 34240, 34243, 34245

**POLYFLEX SEALANTS:** 34516, 34518, 34521, 34525

**ASPHALT RUBBER PLUS and ROADSAVER SEALANTS:** 34200, 34201, 34205, 34210, 34211, 34221, 34222, 34230, 34231, 34241, 34242, 34514, 34515, 34520, 34522, 34530, 34534, 34535

These sealants are hot-applied single component rubberized asphalt products which are supplied in solid block form in packages. To use, the product is removed from the package, heated in an appropriate melter, and then applied to pavement cracks and joints. Specifications, climate and usage applicability for each sealant are shown on the Sealant Product Data sheets.

**MELTING:** These sealants must be melted in a jacketed double boiler type melting unit with effective agitation system. The heat transfer oil in the melting unit should not exceed 525F (274C) during melting of the sealant. The unit must be capable of safely heating the sealant to 410F (210C). **CAUTION:** Do not agitate when adding new blocks of sealant because splashing may occur. Prior to applying sealant, it should be heated to between the recommended pour temperature and the safe heating temperature which is shown on sealant containers.

**APPLICATION METHODS:** Application is best performed with pressure feed wand systems from a sealant melter applicator unit. Lower viscosity sealants can also be applied using gravity feed pour pots. Higher viscosity sealants (typically Asphalt Rubber and Asphalt Rubber Plus) may be difficult to apply using pour pots.

**PAVEMENT TEMPERATURES:** Sealant should be applied when the pavement surface temperature exceeds 40F (4C). Application at lower temperatures may result in reduced adhesion due to possible presence of excess moisture or ice in cracks or joints. If the surface temperature is lower than 40F (4C), it may be warmed by appropriate methods to achieve the minimum required temperature. If conditions require that sealing be performed at lower surface temperatures than 40F (4C), extreme care should be used to insure that the cracks or joints are dry and free from ice and other contaminants. Sealant temperature should be maintained at the safe heating temperature. Applied sealant should be checked by qualified personnel to assure that adequate adhesion is developed.

**PAVEMENT CLEANING PROCEDURES:** For best performance, cracks or joints should be cleaned using appropriate routing, brushing or blowing operations to provide intact bonding surfaces which are free from all dust, moisture or other contaminants. Typical equipment types used include routers, power brush devices, air compressors, water blasters, heat lances, diamond saws, and sand blasters. Equipment types and methods used should be chosen to yield the required results.

**APPLICATION CONFIGURATIONS:** These sealants are applied to cracks and joints in configurations ranging from thin band-aids to sawn reservoirs. For best performance the sealant depth-to-width ratio should not exceed 2 to 1. The lower the depth-to-width ratio (1 to 1 for example), the better the performance. To reduce pick up by vehicle tires or damage due to snow plow abrasion, sealant height should not exceed 1/8" (3 mm.) above the pavement surface.

**ASPHALT CRACKS:** Cracks should be routed to a minimum width of 3/8 inch (1cm) and a minimum depth of 1/2 inch (1.3cm). Following appropriate cleaning, sealant should be applied to a slightly overfilled condition and then leveled to less than a 1/8 inch (3mm) thickness with a squeegee or sealing shoe to produce a band which is 2 to 4 inches (5 to 10cm) wide and is centered over the crack.

**CONCRETE JOINTS:** Backer Rod (ASTM D5249, Type 1) use is required for best sealant performance in concrete joints. Conventional joint designs require that the sealant be recessed approximately 1/4 inch (6mm) below the pavement surface. Recently available performance data, however, indicates that hot applied sealants perform much better in concrete joints if the joint is slightly overfilled and then leveled to a maximum height of 1/8 inch (3mm) above the pavement surface with a slight (less than 2 inch, 5cm) overlap on each top joint edge.

**APPLICATION LIFE:** Application life at application temperatures is approximately 12 to 15 hours. Application life may be extended by adding fresh blocks of sealant as quantity in the kettle decreases. The sealant should be agitated while being applied. The sealant may be reheated to application temperature once, after the initial heat up. Additional reheating of the material may result in degradation of properties. When the application life has been exceeded, Crafco Asphalt Rubber Plus and RoadSaver sealants will begin to thicken, become "stringy" and may then gel. If this should occur, the sealant should immediately be removed from the kettle and discarded. Asphalt Rubber and PolyFlex sealants will tend to soften when overheated or heated for too long.

**APPLICATION PRECAUTIONS:** These products are adhesive and flexible materials used to seal cracks and joints in highway and airfield pavements. In certain situations, additional consideration needs to be given to product selection and application geometries.

1. Parking lots and other areas subjected to slow moving traffic and pedestrians:

The sealant used must be stiff enough at hot summer temperatures to resist pick up and application must be performed so that the sealant is not applied on top of the pavement surface. Several Crafcoc sealants are well suited for these uses as follows.

Maximum Average

Summer Temperatures

95F (35C) +

95F (35C) -

Suggested Sealants

34533, 34200, 34521

34532, 34534

Use of the wrong product for the climatic area and/or use of inappropriate (excessive) applications of sealant can result in pick up and tracking. To reduce initial sealant tackiness immediately after sealant application, Crafcoc DETACK can be used. For additional information, refer to the Crafcoc brochure, Sealing Cracks in Parking and Pedestrian Areas.

2. Pavement which will receive an Overlay, Surface Treatment, or Seal Coat:

In these situations, the sealant will be subjected to effects from heat from the overlay and carriers for the surface treatments and seal coats. If sealant is applied on top of the pavement, and an overlay is then placed, bumps and shoving can occur in the overlay. Refer to the Crafcoc Sheet "Bumps in Overlays Don't Have To Happen", for more information. Solvents or other carriers in surface treatments or seal coats may soften sealant. Prior to placing a surface treatment or seal coat, a test strip should be placed to verify compatibility of the sealant and treatment. If it is desired to place a surface treatment or seal coat quickly after sealant application, Crafcoc DETACK can be applied to the sealant to reduce tack.

3. High Severity Cracked Areas:

Extensively cracked areas of pavements (such as alligator or fatigue cracks in wheel paths) should not be sealed by covering the cracks with sealant because pavement friction may be affected. Areas with extensive cracking can be crack sealed if followed by a surface treatment or overlay which restores surface characteristics.

4. Fuel or Oil Spill Areas:

These sealant products will soften if subjected to fuel and oil spillage, therefore, they should not be used in these areas.

**CLEAN OUT:** If equipment being used requires clean out of pumps and plumbing, follow the manufacturer's clean out instructions. If solvent is used for clean out, insure that the solvent does not contaminate the sealant because sealant dilution and flash problems may occur.

**STORAGE:** Pallets of boxed product are protected with a weather resistant covering. During storage, the protective wrap must be kept on the pallets to prevent boxes from getting wet. If boxes are subjected to moisture, they may lose strength and crush resulting in pallet leaning. If rips in the pallet covering occur during handling, they should be repaired to help maintain packaging integrity. Pallets should be stored on a level surface which is dry and has good drainage. Pallets should not be stacked because crushing of bottom layers may occur. Sealant material properties are not affected by packaging deterioration.

**SAFETY PRECAUTIONS:** Since these sealants are heated to elevated temperatures, it is essential that operations be conducted in manners which assure safety of personnel. All associated with use of the material need to be aware of the hazards of using hot applied materials and safety precautions. Before use, the crew should read and understand product use and safety information on each box of sealant and the product MSDS. This sheet which is supplied with each shipment, describes the characteristics of the product as well as any potential health hazards and precautions for safe handling and use. User should check D.O.T. requirements for transportation of sealant at elevated temperatures (above 212F).

**HAZARDS ASSOCIATED WITH HOT APPLIED MATERIALS:** Skin contact with hot applied materials causes burns. Over exposure to fumes may cause respiratory tract irritation, nausea, or headaches. Appropriate precautions need to be taken to prevent contact with the hot material and to avoid inhalation of fumes for everyone in the vicinity of the sealing operation. Safety precautions should include: 1. protective clothing to prevent skin contact with hot material. 2. Care when adding blocks of product to melpers to reduce splashing. 3. Careful operation and control of wands or pour pots which are used to apply product. 4. Traffic and pedestrian control measures which meet or exceed local requirements to prevent access to work areas while product is still in a molten state. 5. Avoidance of material fumes. 6. Proper application configurations with a minimum amount of excesses of material. 7. Appropriate clean up of excessive applications or product spills.

**ADDITIONAL INFORMATION:** Additional information regarding these products is available by contacting your distributor or Crafcoc, Inc. This information includes 1) Product Data Sheets, 2) Material Safety Data Sheets, 3) Safety Manual, 4) Sealing Cracks and Joints in Parking and Pedestrian Areas, 5) Bumps in Overlays, 6) Shoulder Joint Sealing, 7) Sealant Selection Guide.



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PRODUCT DATA SHEET

**ROADSAVER SILICONE SEALANT**

PART NO. 34902

JANUARY 1996

READ BEFORE USING THIS PRODUCT

**GENERAL** Crafco RoadSaver Silicone Sealant is a uniquely formulated low modulus non-sag sealant produced for sealing joints in portland cement pavements. The sealant is supplied as a ready-to-use one component moisture curing system which provides a lasting and flexible seal. Crafco RoadSaver Silicone Sealant can be used in all typical concrete joint applications on highway and airfield pavements. Crafco RoadSaver Silicone Sealant offers outstanding weathering resistance, remains flexible down to temperatures as low as -50F (-46C), is jet-blast resistant and will maintain field serviceability when exposed to intermittent fuel and oil spills. The sealant bonds strongly to portland cement concrete joints without the use of a primer. RoadSaver Silicone Sealant is applied to pavement joints using bulk dispensing system units such as those available from manufacturers including Pyles and Graco.

**SPECIFICATION CONFORMANCE** Crafco RoadSaver Silicone conforms to specifications of many highway departments, federal agencies, and FAA Airports for low modulus silicone. The Crafco recommended specification is:

<u>Uncured Properties</u>	<u>Specification Limits</u>
Extrusion Rate (ASTM C665) or	25 sec. max.
Extrusion Rate (Mil 8802)	75-250 g/min.
Tack Free Time (ASTM C679) (1)	25-90 minutes
(ASTM D2202)	0.3 in. (.75cm) max.
<u>Cured Properties</u>	<u>Specification Limits</u>
Through Cure Time, 1/2" x 1/2" (12mm x 12mm) (1)	14 day max.
Elongation (ASTM D412-C) (2)	800% min.
Stress at 150% (ASTM D412-C) (2)	45 psi max.
Shore A Hardness (ASTM D2240) (2)	20 max.
Specific Gravity (ASTM D792-A) (2)	1.15-1.515
Adhesion to Concrete (Mil 8802) (3)	20 pli (3.5 kg/cm) min.
Bond and Movement Capability (3)	
+/- 50% (ASTM C719)	Pass 10 cycles
Accelerated Weathering (ASTM C793) (2)	Pass 5,000 hours
Bond to Mortar (AASHTO T132) (3)	50 psi minimum
Tensile Adhesion (4), % ASTM D5329	400% minimum

- NOTES: (1) Tested at 77 ± 3F (25±2C) and 50 ± 5% humidity.  
 (2) Specimens shall be obtained from 1/8 inch (3mm) thickness sheets of material which has been cured for 7 days at 77 ± 3F (25±2C) and 50 ± 5% relative humidity.  
 (3) Specimens cured for 28 days at 77 ± 3F (25±2C) and 50 ± 5% humidity prior to testing  
 (4) Specimens shall be 1/2" x 1/2" x 2" (1.2cm x 1.2cm x 5.0cm), cured 7 days at 77 ± 3°F (25±2C) and 50% ± 5 relative humidity.

**APPLICATION** The unit weight is 10.5 pounds (4.7 kg) per gallon. One gallon will seal 150 feet (45.7m) of 1/2 inch (1.2cm) wide by 1/4 inch (0.6cm) deep joint. Exact yield will vary depending on thickness of sealant, waste, application techniques, etc. For detailed application procedures, refer to the Crafco Application Instructions for RoadSaver Silicone Sealant(December 1995).

**PACKAGING** RoadSaver Silicone Sealant is packaged in plastic lined open head 55 gallon (208 L) drums which contain 50 gallons (189 L) of material. Additionally, for small applications the sealant is available in plastic 5 gallon (19 L) pails and quart (0.95 L) caulking tubes.

**STORAGE LIFE** Store Crafco RoadSaver Silicone Sealant out of direct sunlight, in a cool, dry location. Sealant should not exceed 90°F (32C), or be exposed to excessive humidity. Storage life is approximately six months from date of shipment.

**WARRANTY** CRAFTCO, Inc. warrants that CRAFTCO sealants meet applicable ASTM, AASHTO, Federal or State specifications at time of shipment. Techniques used for the preparation of the cracks and joints prior to sealing are beyond our control as are the use and application of the sealants; therefore, Crafco shall not be responsible for improperly applied, stored, or misused sealant. Remedies against Crafco, Inc., as agreed to by Crafco, are limited to replacing nonconforming product or refund (full or partial) of purchase price from Crafco, Inc. All claims for breach of this warranty must be made within three (3) months of the date of use or twelve (12) months from the date of delivery by Crafco, Inc. whichever is earlier. There shall be no other warranties expressed or implied. For optimum performance, follow Crafco recommendations for sealant installation.



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PRODUCT DATA SHEET

**ROADSAVER SILICONE SL SEALANT**

PART NO. 34903

JANUARY 1998

**READ BEFORE USING THIS PRODUCT**

**GENERAL** Crafco RoadSaver Silicone SL Sealant is a low modulus silicone which offers the performance and durability characteristics of conventional silicone with the ease of installation of self-leveling materials. Crafco RoadSaver Silicone SL is supplied as a ready to use one component moisture curing system which provides a lasting and flexible seal. Crafco RoadSaver Silicone SL Sealant offers outstanding weathering resistance, remains flexible down to temperatures as low as -50F (-46C), is jet-blast resistant and will maintain field serviceability when exposed to intermittent fuel and oil spills. The sealant bonds strongly to concrete joints without the use of a primer. Crafco RoadSaver Silicone SL can be used in all typical concrete joint applications on highway and airfield pavements in all climates. RoadSaver Silicone SL Sealant is applied to concrete joints using bulk dispensing system units such as those available from manufacturers including Pyles/Graco and Johnstone. The leveling characteristics insure that the required joint wetting for development of appropriate adhesion occurs, no tooling is required.

**SPECIFICATION CONFORMANCE** Crafco RoadSaver Silicone SL Sealant conforms to specifications for low modulus silicone for many highway departments, federal agencies and the FAA. The product also meets and exceeds all requirements of ASTM D5893. "Standard Specification for Cold-Applied Single Component, Chemically Curing Silicone Sealant for Portland Cement Concrete Pavements" for type SL sealants. In the following specifications several of the D5893 parameters are more restrictive to better reflect properties of RoadSaver Silicone SL.

<u>ASTM D5893 Physical Requirements</u>	<u>ASTM D5893 Requirements</u>	<u>Crafco RoadSaver Silicone SL Requirements</u>
Cure Evaluation	Pass at 21 days	Pass at 21 day max
Rheological Properties (ASTM D2202)	Type 1 smooth level surface	Type 1, smooth level surface
Extrusion Rate (ASTM C1183)	Type S, 50 ml/min. minimum	Type S, 250 ml/min. minimum
Tack Free Time (ASTM C 679)	5 hr. max.	3 hr. max
Effects of Heat Aging (ASTM C 792)	10% max. Loss	10% max. Loss
Bond, -29C (-20F), 100% Extension		
Non-Immersed	Pass 5 Cycles	Pass 5 Cycles
Water Immersed	Pass 5 Cycles	Pass 5 Cycles
Oven-Aged	Pass 5 Cycles	Pass 5 Cycles
Hardness (ASTM C 661)		
-29C (-20C), Type A2	25 max.	10 max.
23C (73F), Type 00	30 min.	40-80 min.
Flow	No flow	No flow
Rubber Properties in Tension		
Ultimate Elongation	600% min.	800% min.
Stress at 150% Elongation	310 K pa (45 psi) max.	207 K pa (30 psi) max.
Effects of Accelerated Weathering	Pass 500 hours	Pass at 5000 hours
Resilience	75% min.	75% min.
<b>Additional properties of RoadSaver Silicone SL Sealant are:</b>		
Specific Gravity (ASTM D792-A) (1)	1.10-1.40	
Adhesion to concrete (MIL 8802) (2)	20 pli (3.5 kg/cm) min.	
Bond and movement capability +/- 50% (ASTM C719) (2)	Pass 10 cycles	
Bond to mortar (AASHTO T132) (2)	50 psi (34.4 N/cm2) min.	
Tensile Adhesion, % (ASTM D5329) (3)	600% min.	
Notes: (1) Specimens shall be obtained from 1/8 inch (3mm) thickness sheets of material which has been cured for 7 days at 77 +/- 3F (25 +/- 2C) and 50 +/- 5% relative humidity.		
(2) Specimens cured for 28 days at 77 +/- 3F (25 +/- 2C) and 50 +/- 5% humidity prior to testing.		
(3) Specimens shall be 1/2" x 1/2" x 2" (1.2cm x 1.2cm x 5.0cm), cured 7 days at 77 +/- 3F (25 +/- 2C) and 50% +/- 5% relative humidity.		

**APPLICATION** The unit weight is 10.7 pounds per gallon (1.28 kg/L). One gallon will seal 150 feet (45.7m) of 1/2 inch (1.2cm) wide by 1/4 inch (0.6cm) deep joint. Exact yield will vary depending on thickness of sealant, waste, application techniques, etc. Prior to use, the user must read and follow Application Instructions for RoadSaver Silicone Sealants (December 1997) to verify proper product selections, applicator pumps, pavement preparation procedures, application geometry, usage precautions and safety procedures. These instructions are provided with each drum of sealant.

**PACKAGING** RoadSaver Silicone SL Sealant is packaged in plastic lined open head 55 gallon (208 L) drums which contain 50 gallons (189 L) of material. Additionally, for small applications the sealant is available in plastic 5 gallon (19 L) pails and quart (.95 L) caulking tubes.

**STORAGE LIFE** Store Crafco RoadSaver Silicone Sealant out of direct sunlight, in a cool, dry location. Sealant should not exceed 90°F (32.2C), or be exposed to excessive humidity. Storage life is approximately six months from date of shipment.

**WARRANTY** CRAFCO, Inc. warrants that CRAFCO sealants meet applicable ASTM, AASHTO, Federal or State specifications at time of shipment. Techniques used for the preparation of the cracks and joints prior to sealing are beyond our control as are the use and application of the sealants; therefore, Crafco shall not be responsible for improperly applied, stored, or misused sealant. Remedies against Crafco, Inc., as agreed to by Crafco, are limited to replacing nonconforming product or refund (full or partial) of purchase price from Crafco, Inc. All claims for breach of this warranty must be made within three (3) months of the date of use or twelve (12) months from the date of delivery by Crafco, Inc. whichever is earlier. There shall be no other warranties expressed or implied. For optimum performance, follow Crafco recommendations for sealant installation.



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APPLICATION INSTRUCTIONS

**ROADSAVER SILICONE SEALANTS**

PART NO. 34902, 34903, 34908, 34909      JANUARY 1998

**READ BEFORE USING THIS PRODUCT**

**GENERAL:** Crafco RoadSaver Silicone sealants are uniquely formulated low modulus sealants produced for use in sealing joints in portland cement concrete pavements. The sealant is supplied as a single component moisture curing material which provides a lasting weather resistant flexible seal.

**JOINT PREPARATION:** **New Joints:** A minimum cure time of 7 days is recommended before sealing new concrete. To obtain sufficient sealant performance joint spacing should be approximately 20 feet (6m). For optimum performance, joint spacing should be no greater than 20 feet (6m). Joint reservoir depth for 3/8 inch (1 cm) wide joints should be 1 to 1-1/4 inch (2.5 - 3.2cm), and 1/2 inch (1.2cm) wide joints, 1-1/4 to 1-1/2 inch (3.2-3.8cm). A minimum 1/4 inch (6mm) wide joint is recommended. A double cut joint design as illustrated on the back of this page is recommended. This design will help support the sealant and may prevent failure in the wheel paths if non-compressible materials accumulate on the pavement surface and traffic loads continue. We recommend the widening cut not be sawn any deeper necessary for proper sealant configuration. After sawing, immediately flush the joints with water to remove a majority of the saw slurry. After the joints have dried, just prior to applying sealant the remaining residue must be removed by sandblasting "Both joint faces must be adequately sandblasted to remove remaining traces of sawing residue". For effective sandblasting, the nozzle should be positioned within 2 inches (5cm) of the surface being cleaned. After sandblasting the joint should be thoroughly cleaned using clean compressed air with a minimum pressure of 90 psi. Moisture and oil traps are required on compressor unit. The object of the above cleaning operations is to provide vertical, intact, and clean bonding surfaces which are free from all contaminants and are dry. Joints should be carefully inspected to assure that an appropriate level of cleanliness has been achieved. This can be accomplished by rubbing your finger along each joint face, if any evidence of dust and contaminants occur, additional sandblasting should be performed until all dust and contaminants are removed.

**Resealing:** Old sealant should be removed by any appropriate method such as using a joint plow, a router, or hooks. After removal of old sealant, the joint is to be saw cut to an appropriate width to provide clean vertical bonding surfaces which are free from contamination by old sealant. As a general rule, the joint should be sawn to a width which is between 1/8 inch and 1/4 inch (3-6mm) wider than the original joint. The same joint depths listed in the "New Concrete" section should be used. For reservoir width of 3/4 inch (1.9cm), joint depth should be a minimum 1 7/8 inch (4.8cm). The additional sandblasting and cleaning operations contained in the above "New Concrete" section should then be followed.

**Note:** Air voids may develop with self-leveling sealant if the moisture content of the pavement and ambient temperature is high. This phenomenon generally occurs when the sealant has been applied to joints in green concrete during hot and humid conditions. Warm ambient temperatures accelerate pavement hydration and the release of moisture vapors. These moisture vapors will migrate through partially cured material creating air pockets. When the sealant has obtained a full cure no bubbles will develop. A test section should be performed to determine if conditions are adequate so air voids do not develop. Using a non-sag silicone sealant will greatly reduce the risk of air pocket formation. Contact Crafco for further information.

**BACKER ROD PLACEMENT:** After completion of the joint preparation operation and final cleanliness inspection, backer rod should be placed in the joint. A closed cell, expanded polyethylene foam rod should be used. The rod serves as a bond breaker, preventing the sealant from bonding to the bottom of the joint and avoiding excessive stress. It also controls the depth of the sealant bead. The backer rod should be oversized by about 25 percent to form a tight fit in the joint and provide adequate support for proper sealant placement. Tight fit is critical. Self-leveling sealant seeks its own level and will flow into and through any voids. Backer rod can be installed by hand, but a roller device is recommended to speed installation and provide a more uniform depth. Do not puncture backer rod during installation. The following chart lists recommendations for backer rod diameter and depth of installation.

<u>JOINT WIDTH</u>	<u>BACKER ROD DIAMETER</u>	<u>INSTALLATION DEPTH</u>
1/4 in (.6 cm)	3/8 in (1 cm)	1/2 in (1.2 cm)
3/8 in (1. cm)	1/2 in (1.2 cm)	1/2 in (1.2 cm)
1/2 in (1.2 cm)	5/8 in (1.6 cm)	1/2 in (1.2 cm)
5/8 in (1.6 cm)	3/4 in (1.9 cm)	5/8 in (1.6 cm)
3/4 in (1.9 cm)	1 in (2.5 cm)	3/4 in (1.9 cm)
1 in (2.5 cm) up	Contact Crafco	Contact Crafco

**APPLICATION:** RoadSaver Silicone sealant is applied to pavement joints using air powered bulk dispensing systems such as those available from manufacturers including Pyles and Graco or standard caulking guns. The applicator unit must be free of all residue left from other brands of silicone to eliminate contamination and assure proper sealant performance. During application, the sealant is dispensed directly from its container through the applicator hose, wand and nozzle and into the prepared joint. The joint should be filled from the bottom up. RoadSaver Silicone SL sealant is self-leveling and does not require tooling.

RoadSaver Silicone NS sealants are not self-leveling, and must be tooled to the proper geometry. Tooling must be accomplished before the sealant forms a surface skin of cured material (preferably within 5 minutes after application). Tooling may be accomplished using a variety of tools including sections of backer rod, or other appropriately shaped objects. Tooling should be performed so that the sealant is forced against the joint sidewalls and backer rod and so that the sealant forms a recessed concave surface. The recess (NS and SL Products) will vary according to the following joint widths:

<u>JOINT WIDTH</u>	<u>RECESS</u>
1/4 in (.6 cm)	1/4 in (.6 cm) minimum
3/8 in (1 cm)	1/4 in (.6 cm) minimum
1/2 in (1.2 cm)	1/4 in (.6 cm) minimum
5/8 in (1.6 cm)	1/4 in (.6 cm) minimum
3/4 in (1.9 cm)	3/8 in (1 cm) minimum
7/8 in (2.2 cm)	3/8 in (1 cm) minimum
1 in (2.5 cm)	1/2 in (1.2 cm) minimum
1 in (2.5 cm) up	Contact Crafcro

For optimum performance, the width of the sealant bead should be approximately two times the depth. Never install RoadSaver Silicone sealant to a depth greater than the joint width (1 to 1). Sealant bead should be a minimum 1/4 inch (.6cm) thick but no greater than a 1/2 inch (1.2cm) thick.

During application, ambient temperature should be a minimum of 40°F (4C) and the joints must be completely clean and dry for adhesion to fully develop.

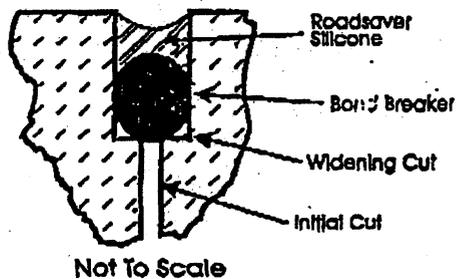
**SEALANT CURING:** After application, RoadSaver Silicone sealant will begin to cure and form a surface skin, generally within 30 minutes. Traffic should be kept off the sealed areas until the sealant is "tack free" as indicated by touching. RoadSaver Silicone will cure throughout within 14 days after application to form a strongly bonded long lasting seal.

**CLEAN UP:** Uncured sealant can be removed from equipment and tools with solvents such as naphtha or mineral spirits. All hoses and lines in the application equipment should be flushed immediately after use. Extra RoadSaver Silicone in drums should be covered with the plastic liner to prevent exposure to air and the drums should be closed before storing until the next use.

**STORAGE LIFE:** Store Crafcro RoadSaver Silicone Sealant out of direct sunlight, in a cool, dry location. Sealant should not exceed 90°F (32C), or be exposed to excessive humidity. Storage life is approximately six months from date of shipment.

**SAFETY PRECAUTIONS:** Prior to use, please read the RoadSaver Silicone sealant Material Safety Data Sheet for establishing appropriate practices during use and application.

**TYPICAL JOINT DESIGN:**



**ADDITIONAL INFORMATION:** Additional information regarding these products is available by contacting your distributor or Crafcro, Inc. This information includes 1) Product Data Sheets, 2) Material Safety Data Sheets, 3) Safety Manual, 4) Sealant Selection Guide.

- Low modulus – the sealant stretches 100 percent in the joint with very little force. This places very little strain on the bond line or joint wall. This maximizes the probability of a successful seal with continuous joint movement. Joint movement caused by temperature, traffic and faulting requires a sealant that does not strongly resist stress and/or shear.
- Fully elastic – the sealant can be stretched to 100 percent or compressed to 50 percent of the joint bond width and held there. When released, it will recover 95 percent or greater of the original dimension. The extension and/or compression can be repeated many times and the sealant will resume its original shape without splits or cracks. Thus, when properly installed in a highway contraction joint, it does not “pump” out of the joint during compression. Nor does it split, crack or lose adhesion during extension.
- Resilient – once cured, the sealant prevents stones and other noncompressibles from entering the joint by “squeezing” them out as soon as the force pushing these noncompressibles into the sealant is removed.
- Good weatherability – its 100 percent silicone rubber is virtually unaffected by sunlight, rain, snow, ozone or temperature extremes.
- Fast cure – typically, the sealant will have a tack-free surface in one hour or less. With this fast cure and recessed joint design, the road can be opened soon after sealing in most applications.
- Long-life reliability – under normal conditions, cured sealant stays rubbery from -45 to 149 C (-49 to 300 F) without tearing, cracking or becoming brittle.
- Compliance with performance requirements – meets and exceeds both Federal Specifications TT-S-001543A Class A (one-part silicone sealants) and TT-S-00230C Class A (one-component sealants) that were written for construction sealants requiring extremely high movement capability. Also meets Canadian Specification 19GP9 Type I and approximately 37 Department of Transportation (DOT) specifications that require a low-modulus sealant with high movement capability.
- The AASHTO-AGC-ARTBA Joint Committee (Task Group 23, Subcommittee on New Highway Materials) included a discussion of silicone joint sealants in its booklet titled “Guide Procedures for Concrete Pavement 4R Operations – 1985.” In addition, the Federal Aviation Administration has published the “FAA Engineering Brief Number 36 – Silicone Joint Sealants.” This publication approves the use of these materials in airfield situations.

### USES

DOW CORNING 888 silicone joint sealant is especially effective for sealing transverse contraction and expansion joints, longitudinal, center line and shoulder joints in Portland Cement Concrete.

DOW CORNING 888 silicone joint sealant can be used as the original sealant in new concrete construction or as a remedial or repair sealant in old construction. In new construction, it provides the *extra* insurance needed if all the “shrink” or contraction cracks do not occur during the initial “weakening” step. Thus, two or three concrete lengths act in unison, stressing a sealant two or three times the design dimensions or movement.

For use in repair or remedial applications where other joint sealing materials have failed because of excessive movement or poor weatherability, DOW CORNING 888 silicone joint sealant can be used to seal irregularly shaped and/or spalled joints. Thus, the joints do not need reforming before sealing. These joints should be dry and free of all old sealing compounds.

### LIMITATIONS

DOW CORNING 888 silicone joint sealant is not recommended for continuous water immersion. It should not be applied in totally confined spaces where the sealant is not exposed to atmospheric moisture. The sealant should never be applied to wet or damp concrete or installed during inclement weather. New concrete should be allowed to cure and dry for at least 7 days of good drying weather. For each day of rain that occurs during that period, an additional day should be added to the 7-day drying time. For “Fastrack” or high early concrete mixes, please

contact your Dow Corning Technical Service Representative.

The sealant bead should be recessed below the pavement surface to prevent abrasion from traffic and snow removal equipment.

The adhesion to substrates other than Portland Cement Concrete should be checked before performing full-scale sealing. Contact your Dow Corning Technical Service Representative.

### HOW TO USE

Low-modulus DOW CORNING 888 silicone joint sealant easily withstands extreme joint movement when properly applied. The sealant will withstand 100 percent extension and 50 percent compression of the original joint width. However, the recommended joint movement design is for  $\pm 25$  percent (50 percent total) and not at the sealant limits. This difference ensures a successful seal when job site joint widths are different than designed widths. Therefore, the joint design dimensions should be less than the ultimate sealant capability.

A thin bead of silicone sealant will accommodate more movement than a thick bead. DOW CORNING 888 silicone joint sealant should be no thicker than 1/2 inch (12.7 mm) and no thinner than 1/4 inch (6.4 mm). Within these limits, the sealant width-to-depth ratio should be 2:1.

In all cases, the sealant must be recessed below the pavement surface at least 3/8 inch with 1/2 inch recess being acceptable in wider joints (see Table I). Consideration should also be given to other possible road-working operations, such as diamond-grinding of the surface. Activities of this type would require the sealant bead to be recessed even deeper.

DOW CORNING 888 silicone joint sealant is a nonsag sealant. This allows its use in vertical curb joints as well as horizontal joints.

Being a non-leveling sealant, DOW CORNING 888 silicone joint sealant must be “tooled” to ensure good contact and adhesion as well as to control sealant depth and provide a recessed surface. Several devices can be used for tooling. Among the simplest and easiest to obtain is the expanded closed-cell polyethylene foam backer rod, which must be larger than the joint width.

**TABLE I: RECOMMENDED BACKER ROD INSTALLATION (SHALLOW CUT)<sup>1</sup>**

Joint Width	1/4"	3/8"	1/2"	3/4"	1"
Recessed Below Surface	3/8"	3/8"	3/8"	3/8"	3/8-1/2"
Sealant Thickness	1/4"	1/4"	1/4"	3/8"	1/2"
Backer Rod Diameter	3/8"	1/2"	5/8"	7/8"	1 1/4"
Total Joint Depth	1-1/8"	1 1/8-1 1/4"	1 1/4-1 3/8"	1 5/8-1 3/4"	2 1/4-2 3/8"

<sup>1</sup>On road surfaces where grinding is planned at a later date, the sealant and backer rod should be installed so that sealant is approximately 3/8 inch below the road surface after grinding is complete. An additional small amount should be added to allow for surface imperfections on the bottom and to provide room for old sealant to pump up from below during rehabilitation work in the summer months.

In new construction where the joint is a new cut, a shallow cut is recommended where the backer rod is placed on the "shelf" or bottom of the joint (see Figure I). Recommended depths are shown in Table I. This design provides a firm support for sealant tooling, making the sealant easier to install, and further ensures good sealant/concrete contact. A shallow cut design also saves saw blades and time.

In repair work where previous sealing materials have been of a joint filling type rather than a joint sealing type, or where the joint is not broadened by

sawing, a standard joint design is recommended in which the backer rod is slightly above the shelf. Extra space (1/4 inch to 1/2 inch) between the bottom of the backer rod and shelf should be provided to allow for possible "pumping" of old joint filling material from the bottom of the joint. It is recommended that care be given to selection of proper oversized backer, so that a firm tooling support is obtained (generally 1/4 inch larger than the joint works quite well).

DOW CORNING 888 silicone joint sealant is part of a system that must include the proper backer rod and

proper installation procedures. The backer rod must be expanded closed-cell polyethylene foam. Where irregularly shaped joints exist, backer rod that is open-cell with an impervious skin is recommended to ensure a tight fit. Several other back-up materials (paper, fibrous ropes and open cell foam) are available, but have proven to be unacceptable. There are several manufacturers of closed-cell polyethylene foam and any may be used.

Please refer to the *Pocket Installation Guide* for more information on applications, preparation and installation information.

**CAUTION**

Before handling sealant, read product and material safety data sheets for detailed use and health information.

Direct contact with uncured sealant may irritate eyes slightly. Avoid eye contact. Do not handle contact lenses with sealant on hands. In case of eye contact, flush eyes with water for 15 minutes.

Uncured sealant may cause injury if swallowed in large amounts. Do not put in mouth. If swallowed, obtain immediate medical attention.

Toxicology studies indicate that repeated, prolonged over-exposure to N-MA causes adverse reproductive effects in laboratory animals. Avoid breathing vapors. Do not use in poorly ventilated spaces. Avoid prolonged skin contact.

KEEP OUT OF REACH OF CHILDREN.

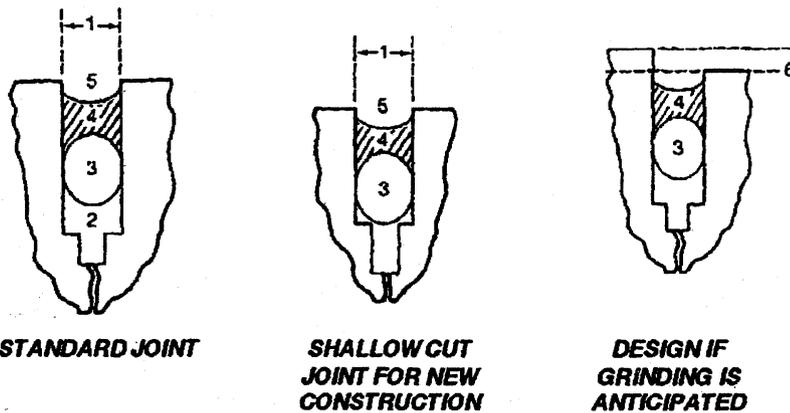
**SHIPPING LIMITATIONS**

None.

**STORAGE AND SHELF LIFE**

When stored in original, unopened containers at or below 32 C (90 F), DOW CORNING 888 silicone joint sealant has a shelf life of 6 months from date of shipment. Keep containers tightly closed.

**FIGURE I: GOOD JOINT DESIGNS**



1. Joint width wide enough to accommodate movement. (For additional information on joint width, see papers by Spells and Klosowski, "Silicone Sealants for Use in Concrete Construction," Vol. 1, No. 1, *American Concrete Institute*, SP-70, 1981; J.B. Cook, "Construction Sealants and Adhesives," Wiley-Interscience, 1970; and J.M. Klosowski, "Sealants in Construction," Marcel Dekker, 1989.)
2. Joint sawed deep enough to allow backer rod/sealant placement and space for pumping of old sealant compounds. NOTE: This applies to standard joints only; void space beneath backer rod in new construction is not needed.
3. Proper backer rod placement to prevent three-sided adhesion.
4. Sealant installed to proper depth and width.
5. Sealant tooled 1/4 inch to 1/2 inch below pavement surface.
6. Depth of lowest slab determines the amount of recess required if grinding is anticipated; once grinding is complete, the sealant will have proper recess below the pavement surface.

**PACKAGING**

DOW CORNING 888 silicone joint sealant is supplied in 29-fl oz (857-mL) disposable plastic cartridges, 4.5-gal (17-L) bulk pails, and 40-gal (151.4-L) bulk drums.

**SAFE HANDLING INFORMATION**

PRODUCT SAFETY INFORMATION REQUIRED FOR SAFE USE IS NOT INCLUDED. BEFORE HANDLING, READ PRODUCT AND MATERIAL SAFETY DATA SHEETS AND CONTAINER LABELS FOR SAFE USE, PHYSICAL AND HEALTH HAZARD INFORMATION. THE MATERIAL SAFETY DATA SHEET IS AVAILABLE FROM YOUR DOW CORNING REPRESENTATIVE, OR DISTRIBUTOR,

OR BY WRITING TO DOW CORNING CUSTOMER SERVICE, OR BY CALLING (517) 496-6000.

**LIMITED WARRANTY - PLEASE READ CAREFULLY**

Dow Corning believes that the information contained in this publication is an accurate description of the typical characteristics and/or uses of the product or products, but it is your responsibility to thoroughly test the product in your specific application to determine its performance, efficacy and safety. Suggestions of uses should not be taken as inducements to infringe any particular patent.

Unless Dow Corning provides you with a specific written warranty of fitness

for a particular use, Dow Corning's sole warranty is that the product or products will meet Dow Corning's then current sales specifications.

**DOW CORNING SPECIFICALLY DISCLAIMS ANY OTHER EXPRESS OR IMPLIED WARRANTY, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR USE.** Your exclusive remedy and Dow Corning's sole liability for breach of warranty is limited to refund of the purchase price or replacement of any product shown to be other than as warranted, and Dow Corning expressly disclaims any liability for incidental or consequential damages.

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**DOW CORNING CORPORATION  
MIDLAND, MICHIGAN 48686-0994**

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**DOW CORNING**

# Dow Corning® 890-SL Self-Leveling Silicone Joint Sealant

DOW CORNING

## 1. PRODUCT NAME

Dow Corning® 890-SL Self-Leveling Silicone Joint Sealant

## 2. MANUFACTURER

Dow Corning Corporation  
Midland, Michigan 48686-0994  
Phone: (517) 496-6000  
FAX: (517) 496-4586

## 3. PRODUCT DESCRIPTION

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is a one-part, cold-applied, easy-to-use, self-leveling silicone material that cures to an **ultra-low-modulus** silicone rubber upon exposure to atmospheric moisture. The cured silicone rubber remains flexible over the entire temperature range expected in pavement applications.

Asphaltic paving materials have low tensile strengths. This requires a sealant that can seal the joint while placing only minimal stress on the asphaltic joint face.

Because of its **ultra-low-modulus** characteristics and good extension/compression recovery (+100/-50 percent of original joint width), Dow Corning 890-SL Self-Leveling Silicone Joint Sealant gives outstanding performance in highway, airport and bridge joints in which extreme movement occurs.

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is designed to perform as a durable joint seal for asphalt and/or concrete pavements.

Because of its ability to firmly adhere to asphalt and concrete pavements, Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is particularly suitable for long-term sealing of asphalt to concrete shoulder joints, while its primary use is for asphalt-to-asphalt and concrete-to-concrete expansion joints. (See Limitations.)

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant features include:

- Easy to use – self-leveling (no tooling step), one-component, cold-applied, ready-to-use as supplied; dispensed directly from the bulk container into the joint by hand or with an air-powered pump.
- All-temperature gunnability – consistency and self-leveling characteristics are relatively unchanged over normal installation temperature range.
- Unprimed adhesion – primer is not required for bonding to asphalt or Portland Cement Concrete. For optimum adhesion, the surface must be clean, dry and frost-free.
- Seals irregular surfaces – the sealant's self-leveling characteristics make it ideal for sealing irregular

joint surfaces by providing adequate contact to the substrate without the need for tooling.

- High movement capability – the sealant will perform in a continuous joint movement of +100/-50 percent.
- Ultra-low modulus – the sealant stretches to 100 percent in the joint with very little stress on the bond line or joint wall. This maximizes the probability of a successful seal with continuous or gradual joint movement. Joint movement caused by temperature, shrinkage, traffic, etc., requires a sealant that does not strongly resist stress and/or shear.
- Fully elastic – the sealant can be stretched to 100 percent or compressed to 50 percent of the joint width and held there. When released, it will recover 95 percent or greater of the original dimension. The extension

## TYPICAL PROPERTIES

These values are not intended for use in preparing specifications or joint designs, but for comparison of rubber properties.

### As Supplied

Color .....	Dark gray
Flow, Sag or Slump .....	Self-leveling
Extrusion Rate, grams per minute .....	275-550
Percent Solids, percent minimum .....	96
Specific Gravity .....	1.26-1.34
Skin-Over Time, at 25°C (77°F), minutes (maximum) .....	60
Cure Time, at 25°C (77°F), days .....	14
Full Adhesion, days .....	14-21

### As Cured—after 21 days at 25°C (77°F) and 50 percent RH

Elongation, percent minimum .....	1400
Joint Modulus, at 50 percent Elongation, psi (kPa) maximum .....	7 (48)
Joint Modulus, at 100 percent Elongation, psi (kPa) maximum .....	8 (55)
Joint Modulus, at 150 percent Elongation, psi (kPa) maximum .....	9 (62)
Adhesion to Concrete, minimum percent Elongation .....	+600
Adhesion to Asphalt, minimum percent Elongation .....	+600
Joint Movement Capability, +100/-50 percent, 10 cycles .....	No failure

Specification Writers: Please obtain a copy of the Dow Corning Sales Specification for this product and use it as a basis for your specifications. It may be obtained from any Dow Corning Sales Office, or from Dow Corning Customer Service in Midland, MI. Call (517) 496-6000.

**Table I: Recommended Backer Rod Installation (Shallow Cut)**

Joint Width, inch	1/4	3/8	1/2	3/4	1
Recessed Below Surface, inch	3/8	3/8	3/8	3/8	3/8-1/2
Sealant Thickness, inch	1/4	1/4	1/4	3/8	1/2
Backer Rod Diameter, inch	3/8	1/2	5/8	7/8	1 1/4
Total Joint Depth, inch	1-1 1/8	1 1/8-1 1/4	1 1/4-1 3/8	1 5/8-1 3/4	2 1/4-2 3/8

<sup>1</sup>On road surfaces where grinding is planned at a later date, the sealant and backer rod should be installed so that sealant is approximately 3/8 inch below the road surface after grinding is complete. An additional small amount should be added to allow for surface imperfections on the bottom and to provide room for old sealant to pump up from below during rehabilitation work in the summer months.

**Table II: Recommended Backer Rod Installation (Shallow Cut) - Metric Equivalents**

Joint Width, mm	6.35	9.53	12.7	19.1	25.4
Recessed Below Surface, mm	9.53	9.53	9.53	9.53	9.53-12.7
Sealant Thickness, mm	6.35	6.35	6.35	9.53	12.7
Backer Rod Diameter, mm	9.53	12.7	5/8"	22.2	31.8
Total Joint Depth, mm	25.4-28.6	28.6-31.8	31.8-34.9	41.3-44.5	57.2-60.3

<sup>1</sup>On road surfaces where grinding is planned at a later date, the sealant and backer rod should be installed so that sealant is approximately 9.53 mm below the road surface after grinding is complete. An additional small amount should be added to allow for surface imperfections on the bottom and to provide room for old sealant to pump up from below during rehabilitation work in the summer months.

and/or compression can be repeated many times and the sealant will resume its original shape without splits or cracks.

- Resilient - once cured, the sealant prevents stones and other noncompressibles from entering the joint by "squeezing" them out as soon as the force pushing the noncompressibles into the sealant is removed.

- Good weatherability - its 100 percent silicone rubber is virtually unaffected by sunlight, rain, snow, ozone or temperature extremes. Most organic sealants stiffen in cold temperatures and soften in warm weather. Organics also degrade and crack in sunlight.

- Cure time - typically, the sealant will have a skin-over time of one hour or less. With a recessed joint design, the road can be opened to traffic soon after sealing in most applications.

- Long-life reliability - under normal conditions, cured sealant stays rubbery from -45 to 149°C (-50 to 300°F) without tearing, cracking or becoming brittle.

**Basic Uses:** Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is designed for sealing joints in asphalt and/or concrete pavements.

Dow Corning 890-SL Self-Leveling Silicone Joint Sealant can be used as the original sealant in new highway construction or as a remedial or repair sealant in old construction. In new construction, it provides a long-lasting seal that will prolong the life of the pavement and prevent water and noncompressibles from entering into the joint and damaging the pavement and foundation.

For use in repair or remedial applications where other joint sealing materials have failed because of excessive movement or poor weatherability, Dow Corning 890-SL Self-Leveling Silicone Joint Sealant can be used to seal irregularly shaped and/or spalled joints. These joints should be clean, dry and free of all old sealing compounds.

**Limitations:** Dow Corning 890-SL Self-Leveling Silicone Joint Sealant is not recommended for continuous water immersion. It should not be

applied in totally confined spaces where the sealant is not exposed to atmospheric moisture. The sealant should never be applied to wet or damp asphalt or concrete pavements or installed during inclement weather.

New concrete must be allowed to cure and dry for at least 7 days of good drying weather. For each day of rain that occurs during that period, an additional day should be added to the 7-day drying time.

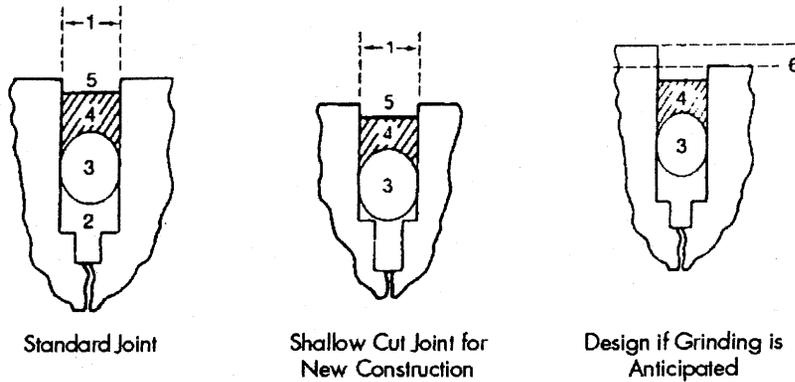
For "Fastrack" or high early concrete mixes, please contact your Dow Corning technical service representative.

The sealant bead must be recessed below the highway surface to prevent abrasion from traffic and snow removal equipment.

The asphalt and concrete pavements should be sound and without signs of deterioration. If the asphalt pavement shows signs of deterioration, sealing the joint may result in further damage to the asphalt.

Several variables can affect the suitability of an asphalt pavement for

**Figure 1. Good Joint Designs**



1. Joint width wide enough to accommodate movement. (For additional information on joint width, see papers by Spells and Klosowski, "Silicone Sealants for Use in Concrete Construction," Vol. 1, No. 1, *American Concrete Institute*, SP-70, 1981; J.B. Cook, "Construction Sealants and Adhesives," Wiley-Interscience, 1970; and J.M. Klosowski, "Sealants in Construction," Marcel Dekker, 1989.)
2. Joint sawed deep enough to allow backer rod/sealant placement and space for pumping of old sealant compounds. NOTE: This applies to standard joints only; void space beneath backer rod in new construction is not needed.
3. Proper backer rod placement to prevent three-sided adhesion.
4. Sealant installed to proper depth and width.
5. Sealant recessed a minimum of  $\frac{3}{8}$  inch to  $\frac{1}{2}$  inch (9.53 mm to 12.7 mm) below pavement surface.
6. Depth of lowest slab determines the amount of recess required if grinding is anticipated; once grinding is complete, the sealant will have proper recess below the pavement surface.

joint sealing, including thickness, mix type compaction, age and overall structural integrity of the asphalt pavement.

In addition, pavements with poor base conditions, including numerous patches, misaligned slabs and mid-slab cracking, are not candidates for saw and sealing techniques<sup>1</sup>.

Suitability of *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* for sealing asphalt expansion joints should be determined by thoroughly testing the product in your specific applications. For further details, please contact your *Dow Corning* technical service representative.

Joints should be prepared by saw cutting and not routing. Routing of asphalt and concrete pavements can cause microfractures in the pavement that can lead to poor joint performance.

Not intended for medical use.

**Packaging:** *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is supplied in 29-fl oz (857-mL) disposable plastic cartridges, 4.5-gal (17-L) bulk pails, and 50-gal (189-L) bulk drums.

**Shipping Limitations:** None.

**Storage and Shelf Life:** When stored in original, unopened containers at or below 32°C (90°F), *Dow Corning*

890-SL Self-Leveling Silicone Joint Sealant has a shelf life of 6 months from date of shipment from *Dow Corning*. Keep containers tightly closed.

#### 4. TECHNICAL DATA

See Typical Properties for technical data for *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant*.

#### 5. INSTALLATION

**Joint Design:** Ultra-low-modulus *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* easily withstands extreme joint movement when properly applied. The sealant will withstand 100 percent extension and 50 percent compression of the original joint width. However, the recommended movement design is for +50 percent and -25 percent and not at the sealant limits. This difference ensures a successful seal when job site joint widths are different than designed widths. Therefore, the joint design dimensions should be less than the ultimate sealant capability.

A thin bead of silicone sealant will accommodate more movement and result in less bond line stress than a thick bead. *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* should be no thicker than  $\frac{1}{2}$  inch (12.7 mm) and no thinner than  $\frac{1}{4}$  inch (6.4 mm). Within these limits, the sealant width-to-depth ratio should be 2:1.

In all cases, the sealant must be recessed below the road surface at least  $\frac{3}{8}$  inch (9.53 mm) with  $\frac{1}{2}$  inch (12.7 mm) recess being acceptable in wider joints. (See Tables I and II.)

**Application:** *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is an easy-to-use, self-leveling sealant that does not require a separate tooling step as conventional, non-sag sealants do. Because the sealant is self-leveling, it cannot be used on vertical surfaces.

<sup>1</sup>*Highway & Heavy Construction*, June 1988, p. 53.

Before attempting to seal joints in new asphalt, the asphalt must be given sufficient time to cool and to "cure," so that damage will not result from sawing. This time will depend upon a number of factors, such as mix design, time of year for placement, geographic location and past experiences. The asphalt must also be completely dry prior to sealant installation.

In new construction where the joint is a new cut, a shallow cut may be used where the backer rod is placed on the bottom of the joint. (See Figure 1.) A shallow cut saves time and saw blades.

In repair or remedial work where previous sealant materials have failed, care should be taken to completely remove the failed sealant from the joint faces. A standard joint design is recommended in which the backer rod is slightly above the shelf. Extra space should be provided to allow for possible "pumping" of old failed joint sealant that may have fallen below the joint.

When *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is used for sealing reflection cracks in asphalt pavements, additional joint preparation steps must be used. Cracks that have formed in the asphalt pavement must be totally removed by saw cutting. This can be accomplished by

saw cutting along both sides of the crack, exposing freshly cut and sound asphalt joint faces.

When *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is used to seal asphalt-to-concrete shoulder joints, care must be taken to ensure that the asphalt is completely removed from the concrete face to which the sealant will be bonding. This can be accomplished by saw cutting tightly along the concrete. A fresh and sound joint face must also be prepared in the asphalt by saw cutting.

*Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is part of a system that must include the proper backer rod and proper installation procedures. Please refer to *Dow Corning's Installation Guide for Silicone Pavement Sealants* (Form No. 61-507) for more information on applications, preparation and installation.

**Caution:** Before handling sealant, read product and material safety data sheets for detailed use and health information.

Direct contact with uncured sealant may irritate eyes slightly. Avoid eye contact. Do not handle contact lenses with sealant on hands. In case of eye contact, flush eyes with water for 15 minutes.

Uncured sealant may cause injury if swallowed in large amounts. Do

not put in mouth. If swallowed, obtain immediate medical attention.

Toxicology studies indicate that repeated, prolonged overexposure to N-MA causes adverse reproductive effects in laboratory animals. Avoid breathing vapors. Do not use in poorly ventilated spaces. Avoid prolonged skin contact.

KEEP OUT OF REACH OF CHILDREN.

**Safe Handling Information:** PRODUCT SAFETY INFORMATION REQUIRED FOR SAFE USE IS NOT INCLUDED. BEFORE HANDLING, READ PRODUCT AND MATERIAL SAFETY DATA SHEETS AND CONTAINER LABELS FOR SAFE USE, PHYSICAL AND HEALTH HAZARD INFORMATION. THE MATERIAL SAFETY DATA SHEET IS AVAILABLE FROM YOUR DOW CORNING REPRESENTATIVE, OR DISTRIBUTOR, OR BY WRITING TO DOW CORNING CUSTOMER SERVICE, OR BY CALLING (517) 496-6000.

## 6. AVAILABILITY AND COST

**Availability:** *Dow Corning 890-SL Self-Leveling Silicone Joint Sealant* is available from Dow Corning Corporation and its authorized distributors.

**Cost:** Contact your local Dow Corning representative. See list on the last page for the nearest Dow Corning sales office.

# DELASTIC NEOPRENE COMPRESSION SEALS

THE D.S. BROWN COMPANY is an Ohio-based, wholly American-owned manufacturer of rubber products for the construction industry.

Founded in 1890 and incorporated in 1949, The D.S. Brown Company has become a leader in extruded rubber seals and gaskets in the past 31 years. Working with custom compounds, developed in-house, excellent results have been achieved in close tolerance shapes for sealing purposes. As early as 1960, the company was producing the first generation of neoprene highway compression seals. These were improved upon and marketed under the tradename "DELASTIC"® here and abroad.

Working closely with state highway departments and consulting firms, the quality and specifications of the products are kept to the current state of the art. Inquiries about the systems

described herein are welcomed. This brochure is primarily intended as a selection guide and general background information for the products presented.

## Material

Unless noted otherwise, the DELASTIC preformed compression seals are extruded from compounds of neoprene (polychloroprene) which meet the current applicable ASTM Standard Specifications for concrete pavements or bridges. (See back cover.)

## Installation

In all instances, the joint sides must be reasonably clean and free of spalls with a properly designed width. Depending on seal size and type, tools are available for sale or rental (see back cover) to facilitate insertion. Lubricant-adhesives are used in most applications. THE D.S. BROWN COMPANY markets "Delastiseal"

(meeting ASTM D 2835 standards) and "Delastibond" (urethane-based, 60% solids) to lubricate and bond during the installation of the seal with the joints.

The desirable installation temperature on outdoor job sites ranges from a maximum of 75-80°F (seals become difficult to install at higher readings) to a low of 35-40°F (the lubricant/adhesives have impaired effectiveness in cold air.)

## Delivery

The extrusions are shipped on either reels, spools, or in boxes in ordered lengths, marked as required by the customer. The lubricant/adhesives are supplied in one or five gallon containers, clearly labeled with the necessary data.

## DELASTIC "E" AND "V" SERIES

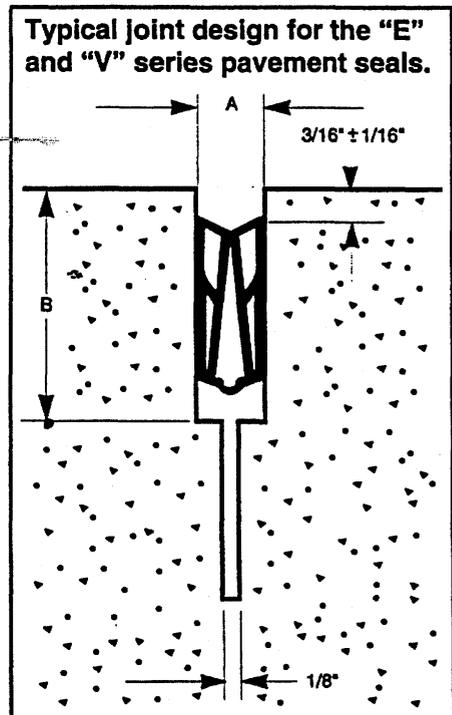
The "E" and "V" series Delastic® preformed neoprene seals are the primary sealing system for concrete pavement slabs in all major applications - primarily in concrete roadways, airport aprons and runways.

Preformed neoprene seals are designed to prevent the entry of harmful and damaging particles and moisture into the concrete joint. The seal performs this duty by exerting constant compressive force on the joint face while allowing the concrete to expand and contract due to temperature and physical changes that may occur.

Delastic® preformed neoprene seals are recognized by the FHWA, Corps of Engineers, U.S. Air Force, consulting engineers and other agencies as a long-lasting and effective concrete pavement joint seal.

As joint seals receive increasing attention in the industry, the superior life cycle value of The D.S. Brown preformed neoprene compression seal becomes apparent. Some of the other benefits that accompany the use of our preformed neoprene compression seal is its ability to seal joints in concrete where high moisture is present, its resistance to jet fuel, the speed of installation, cleanliness of the product, ease of inspection and the dramatic reduction in concrete joint spalling.

The D.S. Brown Company is the only manufacturer of the preformed neoprene seal in the industry that also markets its product, this allows The D.S. Brown Company to offer both the service and quality the customer requires.

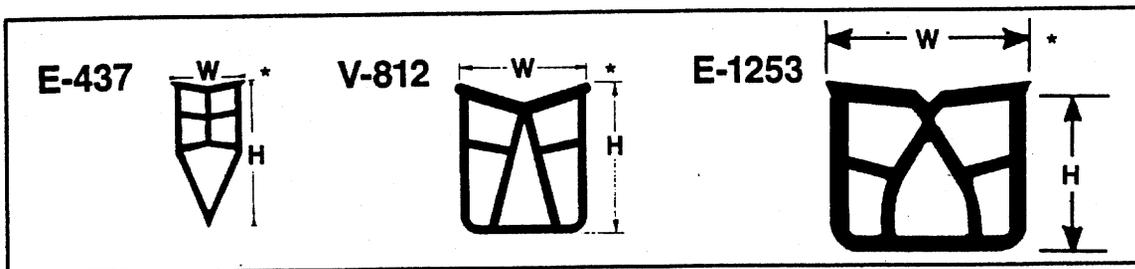


# "E" AND "V" SERIES PAVEMENT SEALS

Delastic® Seal Catalog No.	SEAL CHARACTERISTICS			JOINT DESIGN CRITERIA		
	Nominal Width (w)	Nominal Height (H)	Max. Movement <sup>1</sup>	Narrowest Opening <sup>2</sup> (A)	Widest Opening <sup>3</sup> (A)	Minimum Depth (B)
E-437	7/16 (11.11)	15/16 (23.81)	0.184 (4.67)	0.187 (4.75)	0.371 (9.42)	1-1/4 (31.75)
V-562	9/16 (14.29)	11/16 (17.46)	0.178 (4.52)	0.250 (6.35)	0.478 (12.14)	1-3/8 (34.93)
V-687	11/16 (17.46)	13/16 (20.64)	0.259 (6.58)	0.325 (8.26)	0.584 (14.83)	1-1/2 (38.10)
V-812	13/16 (20.64)	15/16 (23.81)	0.348 (8.84)	0.350 (8.89)	0.698 (17.73)	1-5/8 (41.28)
E-1006	1 (25.40)	1 (25.40)	0.450 (11.43)	0.400 (10.16)	0.850 (21.59)	1-7/8 (47.63)
E-1253	1-1/4 (31.75)	1 (25.40)	0.612 (15.54)	0.450 (11.43)	1.062 (26.97)	2-1/8 (53.98)
V-1625	1-5/8 (41.28)	1-1/8 (28.58)	0.781 (19.84)	0.600 (15.24)	1.381 (35.08)	2-1/2 (63.50)
E-2000	2 (50.80)	1-1/2 (38.10)	0.950 (24.13)	0.750 (19.05)	1.700 (43.18)	3 (76.20)
E-2500	2-1/2 (63.50)	2-1/2 (63.50)	1.100 (27.94)	0.775 (19.69)	2.125 (53.98)	3-1/2 (88.90)
E-3000	3 (76.20)	2-1/2 (63.50)	1.260 (32.00)	1.200 (30.48)	2.550 (64.77)	3-1/2 (88.90)

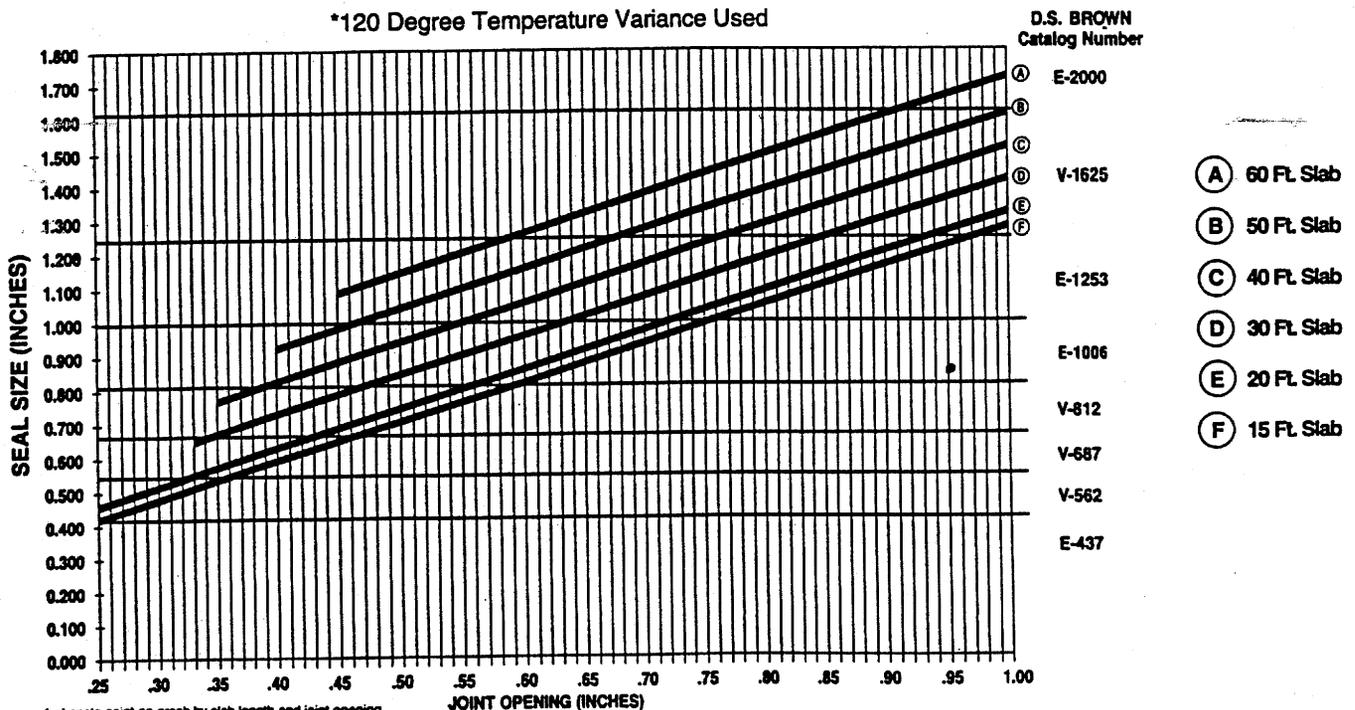
NOTES: \* Thickness of seal wall and internal web are not drawn to scale.  
<sup>1</sup> Maximum movement that seal will accommodate in joint of correct design.  
<sup>2</sup> A narrower opening will put excessive stress on seal and may cause premature failure.  
<sup>3</sup> A wider opening may not provide sufficient compressive force to hold seal in place.  
 Meets ASTM D 2628 and AASHTO M-220 Standard Specifications.

Metric dimensions shown in parentheses. (MM)



## SEAL SIZE CHART

\*120 Degree Temperature Variance Used



1. Locate point on graph by slab length and joint opening.  
 2. Proceed to the right side of graph and order recommended catalog number.  
 \*\* Specifications are often used to determine seal size. Contact your D.S. BROWN representative for individual needs.

# INSTALLATION AND SPECIFICATIONS

## DELASTIC® Installation Tools

To facilitate seal installation, The D.S. Brown Company offers a complete line of self-manufactured tools and machines for sale or rental. From the simple handroller (Mark I) to the highly productive DELASTALL No. 104 automatic installing machine, the right tool for the right size seal is on hand for contractor customers.

## Size Applications:

Trough and Tapper for seals from 1-1/4 to 4 inches nominal width.

MARK X for seals from 1-5/8 to 2-1/2 inches.

MARK XX for seals from 3 to 6 inches.

DELASTALL No. 104 Auto-Installer primarily for pavement seals (7/16 to 1-5/8 inches).

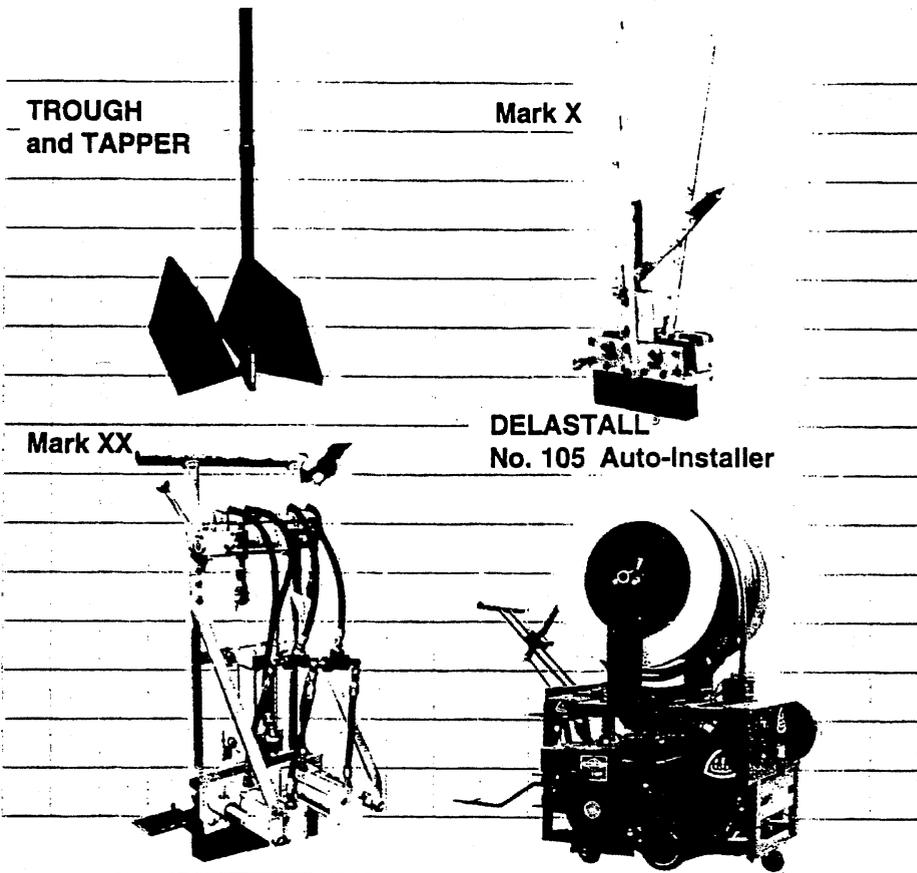
## Lubricants

"Delastiseal" and "Delastibond" are the names of the lubricant/adhesives supplied by The D.S. Brown Company. Specification sheets are available when required. The sales/service personnel of the seal division is glad to advise on type and quantity of lubricant required.

The use per lin. ft. factor varies so considerably for the many different extrusions and applications that it is impractical to provide such information in this brochure. (Example: 4-5 inch size seal of CV or H type may require about 1 gallon per 100 ft. of seal.)

## Material/Specifications

For concrete pavement seals (E and V series), ASTM Standard Specification D 2628-81 apply (not reproduced here). For series H and CV, the ASTM Standard Specification for PREFORMED POLYCHLOROPRENE ELASTOMERIC JOINT SEALS FOR BRIDGES, Designation D 3542-82 is met. (See table to the right.) Lubricant/adhesives shall conform to ASTM 2835/ASTM D-4070 respectively.



ASTM D3542-82 Physical Requirements for Preformed Elastomeric Joint Seals		
	Requirements	ASTM Method
Tensile strength, min, psi (MPa)	2000 (13.8)	D 412
Elongation at break, min, %	250	D 412
Hardness, Type A durometer, points	55 ± 5	D 2240 (modified) <sup>A</sup>
Oven aging, 70 h at 212°F (100°C):		D 573
Tensile strength, max, % loss	20	
Elongation, max, % loss	20	
Hardness, Type A durometer, points change	0 to 10	
Oil swell, ASTM Oil No. 3, 70 h at 212°F (100°C):		
Weight change, max, %	45	D 471
Ozone resistance <sup>B</sup> :		
20% strain, 303 mPa of ozone in air (the volume fraction of ozone is 300 ppm in air at 1 atm), 70 h at 104°F (40°C), wiped with toluene to remove surface contamination	no cracks	D 1149
Low-Temperature recovery <sup>C</sup> , 72 h at 14°F (-10°C), 50%:		
Deflection, min, %	88	Section 7 <sup>D</sup>
Low-temperature recovery <sup>C</sup> , 22 h at -20°F (-29°C), 50%:		
Deflection, min, %	83	Section 7 <sup>D</sup>
High-temperature recovery <sup>C</sup> , 70 h at 212°F (100°C), 50%:		
Deflection, min, %	85	Section 7 <sup>D</sup>
Compression-deflection properties:		D 575 Method A (modified) <sup>E</sup>
LC min, %	See 5.1.4 <sup>D</sup>	
LC max, %	See 5.1.5 <sup>D</sup>	
Movement range, %	See 5.1.6 <sup>D</sup>	

THE D.S. BROWN COMPANY

SINCE 1894



P. O. Box 158 • 300 East Cherry Street • North Baltimore, Ohio 45872-0158 • U. S. A.

Telephone: 419-257-3561 • FAX: 419-257-2200

LABORATORY TEST REPORT - ASTM D-2628

Date 7-11-97

Delastic Preformed Joint Sealer Part No. V-687

Lot No. \_\_\_\_\_

Width 11/16"

Remarks

TYPICAL

<u>Property</u>	<u>Method</u>	<u>Test Results</u>	<u>Required</u>
Tensile strength, psi	D-412	<u>2258</u>	2000 min.
Elongation at break, %	D-412	<u>450</u>	250 min.
Hardness, Type A Durometer	D-2240	<u>56</u>	55 ± 5
Oven aging, 70 hr. @ 212°F	D-573		
Tensile strength, % change		<u>-2</u>	-20 max.
Elongation, % change		<u>-5</u>	-20 max.
Hardness, point change		<u>9</u>	0 to +10
Oil swell, ASTM oil 3, 70 hr. @ 212°F	D-471		
Weight change, %		<u>30</u>	45 max.
Ozone resistance, 20% strain	D-1149		
300 ppm in air, 70 hr. @ 104°F		<u>NC</u>	No Cracks
Low temperature stiffening, 7 days	D-2270		
@ 14°F, hardness, points change		<u>7</u>	+15 max.
High temperature recovery, %			
70 hr. @ 212°F, 50% deflection		<u>95</u>	85 min.
Low temperature recovery, %			
72 hr. @ 14°F, 50% deflection		<u>99</u>	88 min.
Low temperature recovery, %			
22 hr. @ -20°F, 50% deflection		<u>94</u>	83 min.
Compression - deflection,			
80% nominal width, lb/in.		<u>7.30</u>	3.5 min.

IN WITNESS:

David Limon  
 SUBSCRIBED AND SWORN TO BEFORE ME THIS  
11th DAY OF July, 1997.

James A. Schroeder  
 NOTARY PUBLIC - STATE OF OHIO  
 MY COMMISSION EXPIRES: March 10, 2002



**INSTALLATION and INSPECTION**

**STORAGE:**

The Preformed Neoprene seal is delivered either in cardboard reels or large wooden cable reels. The proper storage of the cardboard reels requires the boxes be protected from moisture to keep the cardboard from deteriorating. The large wooden cable reels should be covered by a tarpaulin to keep the seal clean and damage free. The lubricant/adhesive should be kept from freezing.

**JOINT PREPARATION:**

To form the joint, a two-stage sawing operation is performed. The first saw-cut is designed for control cracking. The second saw-cut will create the proper shape factor for the Preformed Neoprene seal. This saw-cut is made using a water cooled diamond blade saw capable of holding a tolerance of  $\pm 1/16"$ . The saw-cut is inspected for proper width, depth and the face of the joint must be at 90 degrees to the surface of the pavement. If spalling occurs due to the sawing operation, it must be repaired prior to seal installation. The longitudinal saw-cut operation is not performed until the pavement is determined to be level from one slab to the next. Any horizontal deviation greater than  $1/16"$  from one slab to the next shall be corrected before sawing. If the horizontal deviation is not corrected the installation machines may experience difficulty in installing the seal.

Once the secondary saw-cut is made, the joint is pressure washed with clean water and blown out with compressed air. Sandblasting will be needed if called for in the specification of the project.

The joint is now ready for installation of the Preformed Neoprene seal. There have been various types of installation machines used over the last 30 years. The installation machine should be capable of installing the seal at the specified depth without cutting, nicking or twisting the seal. The installation machine also must be capable of installing the seal with 3% or less stretch. The D. S. Browns' Delastall® gasoline powered machine is capable of holding 5 gallons of lubricant/adhesive and a spool of seal. It has large powered compression wheels that deliver the Preformed Neoprene seal to the joint with minimal stretch, installing it to the proper depth (adjustable) while applying the lubricant/adhesive directly to the sides of the seal. Other installation machines on the market compress the seal by means of roller bearings. These roller bearings squeeze the neoprene ahead of the bearings and ultimately stretch the Preformed Neoprene, which results in poor performance and premature failure of the seal. Hand installation usually results in damage to the seal from the use of tools that puncture, or stretch the seals to over 20% their original length.

**LUBRICANT/ADHESIVES:**

The lubricant adhesive is used mainly to facilitate the installation of the Preformed Neoprene seal. The lubricant/adhesive must contain a minimum of 24% solids, be uniform, contain no lumps, have the

correct viscosity and have a drying time between eight and twenty minutes.

The containers of lubricant/adhesive should be labeled with the manufacturer's name, catalog number, lot number, and expiration date. Also, an MSDS must accompany all shipments for the safety of the user.

The lubricant adhesive will begin thickening at 32°F. When sealing operations occur where the air temperature is below 32°F, the lubricant/adhesive should be stored in a heated warehouse until needed.

Cleaning of the equipment and tools in contact with the lubricant/adhesive is accomplished with the use of toluene or other applicable solvents. The disposal of the empty lubricant/adhesive containers remaining from the use of the Preformed Neoprene seal system should be properly disposed of in a class II licensed landfill (check local RCRA division of the EPA for details).

### **INSTALLATION SEQUENCE:**

The proper installation sequence for Preformed Neoprene seal is to install the longitudinal seal first. After allowing the glue to dry (approximately 20 minutes), the longitudinal seal is cut with a sharp blade at the intersection of the transverse joint. The transverse joint seal is then installed through the cut in the longitudinal seal to form a tight intersection. The transverse seal should be installed in one continuous piece. The transverse seal will exert outward force on the end cut of the longitudinal seal to form a tight intersection.

### **INSPECTION:**

Stretching the seal during installation is the major cause of premature failure of the Preformed Neoprene seal. Inspecting for stretch should be done very early in the sealing process. The inspection involves loosely laying a piece of Preformed Neoprene seal the entire width of the pavement and cutting it at the exact width of the pavement. The seal is then installed in the joint. Any excess amount of seal remaining at the end of the joint is due to stretch. The length of this excess is measured and a stretch percentage is calculated by dividing the excess length by the original length. Stretch greater than 3% is unacceptable; some projects specify stretch of 1% or less.

Proper depth of the seal is very important. If the seal is too deep, the joint will gather incompressible material and spall the concrete. If the seal is too shallow, the seal may receive abrasive wear from tire contact or be pulled out by snowplows. Therefore, it is recommended that the Preformed Neoprene seal be recessed 3/16" from the surface of the pavement  $\pm 1/16"$ . When beveled joints are being sealed, the top of the seal should be 1/16" to 3/16" below the bottom edge of the bevel.

Visual inspection for twists, cuts, pop-ups, and separation of butt-joints shall be performed. A rule-of-thumb is any situation that causes the top outer edge of the seal from making contact with the face of the joint is unacceptable and must be repaired.

## CONCLUSION:

Preformed Neoprene compression seals have been recognized by the F.H.W.A.<sup>3</sup>, Corps of Engineers and other agencies and consulting engineers as a long-lasting and effective concrete pavement joint seal. As joint seals receive increasing attention in the industry, the life-cycle value of the Preformed Neoprene compression seals becomes apparent. Some of the benefits that accompany the use of Preformed Neoprene compression seals is the ability to seal joints in "green" concrete where high moisture is present. Other benefits include speed of installation, cleanliness of product and the dramatic reduction in joint spalling when Preformed Neoprene seals are utilized.<sup>4</sup>

## REFERENCES

1. Peterson, Dale E. and McBride, Joseph. Evaluation of Preformed Elastomeric Pavement Joint Sealing Systems. Transportation Research Board, 4-9/1. 1979
2. Brown, Delmont D. Third World Congress on Joints Proceedings. Toronto, Canada. 1991  
Hall, F. K., Ritzi, J. H., and Brown, D. D. Study of Factors Governing Contact Generation in Neoprene Preformed Compression Seals. Highway Research Record No. 200. 1967
3. Papet, Louis M. Technical Paper - Preformed Compression Seals for PCC Pavement Joints. F.H.W.A. Memorandum. 1989
4. Darter, M.I., Smith, K.D., Peshkin, D.G. Field-Calibrated Mechanistic-Empirical Models for Jointed Concrete Pavements. Transportation Research Board Proceedings No. 910757. 1991

**TechStar, Inc.**

532 Sutton Place, Findlay, Ohio 45840  
Telephone: 419-424-0888, Fax: 419-424-5959

**CERTIFICATE OF COMPLIANCE  
W-050 PAVEMENT EXPANSION JOINTS**

DATE: January 5, 1999

TechStar Reference: TechStar Incorporated Invoice #9735  
ODOT 180(97) Athens Co., Ohio

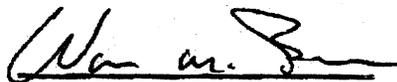
Customer: Kokosing Construction  
886 McKinley Ave.  
Columbus, OH 43222

Quantity  
2500 feet

Items  
W-050 Seal

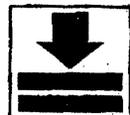
This is to certify that the TechStar W-Seal and process used in the manufacture of the items supplied as above are in strict accordance with AASHTO and conform to the TechStar and Advanced Elastomer Systems material specifications. The W-050 Seal used was co-extruded of virgin Santaprene thermoplastic. Sufficient TechStar 1-K adhesive was supplied to complete all 2500 feet of pavement seal.

TechStar, Incorporated

  
Warren M. Brown



Joints



Bearings

## PRODUCT DATA SHEET

# Santoprene<sup>®</sup>

THERMOPLASTIC RUBBER

### SANTOPRENE rubber 121-67 W175

A black thermoplastic UV grade elastomer with good fluid resistance, formulated to replace thermoset elastomers such as EPDM, polychloroprene, and chlorosulfonated polyethylene. It can be processed using injection molding, extrusion (especially thin-wall), blow molding or other melt processing techniques. Supplied as free-flowing pellets in 25 kilogram (55 pound) moisture barrier bags.

Property	Test Method	Test Unit	Typical Value
Hardness, 5 second	TPE-0169 (ASTM D 2240)	Shore A	67
Specific gravity	TPE-0105 (ASTM D 792)		0.97
Tensile strength, ultimate*	TPE-0153 (ASTM D 412)	MPa (psi)	7.5 (1050)
Elongation, ultimate*	TPE-0153 (ASTM D 412)	percent	410
100% Modulus*	TPE-0153 (ASTM D 412)	MPa (psi)	3.0 (420)
Compression set, 168 hrs.	TPE-0016 (ASTM D 395, Method B)	percent @ 23°C (73°F)	23
		percent @ 100°C (212°F)	38
Tension set	TPE-0053 (ASTM D 412)	percent	10
Tear strength	TPE-0056 (ASTM D 624)	kN/m @ 23°C (pli @ 73°F)	24.5 (140)
		kN/m @ 100°C (pli @ 212°F)	10.2 (58)
Brittle point	TPE-0089 (ASTM D 746)	°C (°F)	<-80 (<-76)

Values are for injection molded plaques, side gated  
62.8 mm x 117.5 mm x 3.0 mm (3.26" x 4.626" x 0.120")

\* Properties are measured across the flow

For order assistance, call 1-800-ELASTOMER (1-800-352-7885).



**Advanced  
Elastomer  
Systems**

The worldwide leader in engineered TPEs

# SANTOPRENE rubber 121-67 W175

## KEY FEATURES

- Dielectric constant 2.3, dielectric strength at 3.17 mm (125 mil), 19.6 kv/mm (500 v/mil)
- Flame resistant HB material
- Continuous temperature rating 1000 hrs. @ 135°C (275°F)
- Excellent flex fatigue resistance
- Excellent ozone resistance
- Excellent UV resistance

Extrudes thin sections with excellent definition (down to 0.33 mm [1.3"] radius). Long runs with minimal build-up of material on screen packs or narrow die sections.

## PROCESSING STATEMENT

SANTOPRENE thermoplastic rubber is a shear-dependent material that can be processed on conventional thermoplastic equipment for injection molding, extrusion or blow molding. SANTOPRENE rubber has a wide temperature processing window from 177 to 232°C (350 to 450°F). Desiccant drying for 3 hours at 82°C (180°F) is recommended. For extrusion, a general purpose screw with a compression ratio of 2.5 to 3.0 is recommended. Material can be recycled.

SANTOPRENE rubber is incompatible with acetal and PVC. Please consult our Material Safety Data Sheet and Rheology/Processing Brochure.

## AGING PROPERTIES

- Retained properties after oven air aging 168 hrs. @ 150°C (302°F)
  - Retained tensile strength, 98%
  - Retained elongation, 97%
- Retained properties after 168 hrs. @ 100°C (212°F) in IRM 903 oil
  - Retained tensile strength, NA
  - Retained elongation, NA
  - Weight change, NA

---

For additional technical, sales, and order assistance:

**ADVANCED ELASTOMER SYSTEMS, L.P.**  
388 S. Main Street  
Akron, OH 44311-1059

**Technical Assistance:**  
1-800-305-8070  
**Sales and Order Assistance:**  
1-800-352-7866

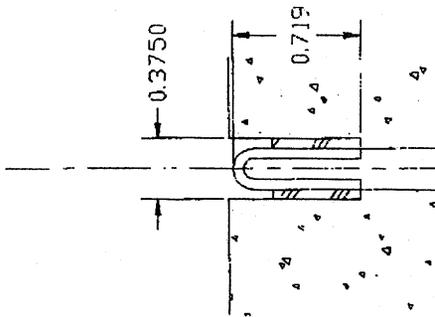
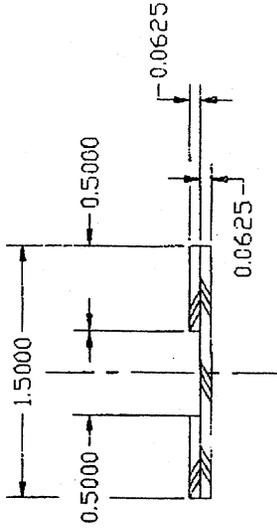
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rev. 2/93

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E



INSTALLED SECTION VIEW

FILE: C:\ACADR12\TECHSTAR\W-50

*TechStar, Inc*

532 SUTTON PLACE, FINDLAY, OHIO 45840  
TELEPHONE: 419-424-0888, FAX: 419-424-5959

"Wseal" STYLE COMPRESSION SEAL  
PART NO. W-50

DRAWN BY: RBB SCALE: NTS MAT'L

CHECKED: DATE: 3/17/97 DRAWING NO:

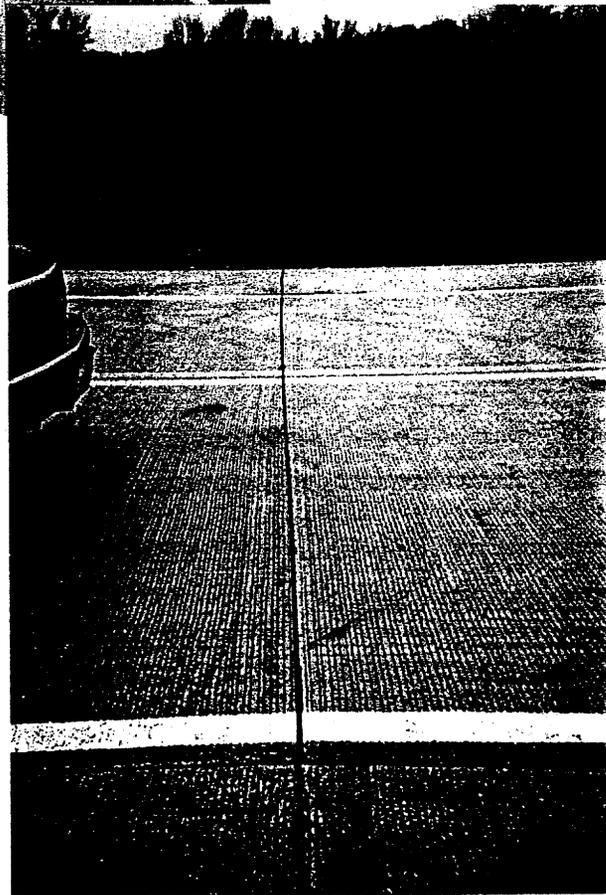
APP'D: REV: 4/24/98 1 OF 1

## W-SEAL Pavement Seal, US 50, Athens Co, ODOT Installed in November 1997

W-Seal 050 Pavement Seal was installed as part of a pavement seal evaluation program under ODOT supervision. Expansion Joints were sawed in the new concrete roadway & four different manufacturer's sealing systems were installed to compare their relative performance. Two traditional Neoprene pre-formed seals were supplied as well as TechStar pre-formed W-Seal seal and a Silicone pourable sealant.



Each manufacturer was given a section of highway in each direction of traffic in the four lane highway to install their pavement seal material. Each expansion joint was sawed at 3/8" opening per ODOT specifications. Each manufacturer had approximately 25 joints in their section and 2500 feet of total joint. The joints were sawed and blown clean immediately prior to seal installation. The following photographs show the first installations of W-Seal pavement seal by the general contractor, Kokosing, to instruct laborers in the appropriate procedures for installing the W-050 Pavement Seal.



## W-SEAL Pavement Installation, November 1997

page 2



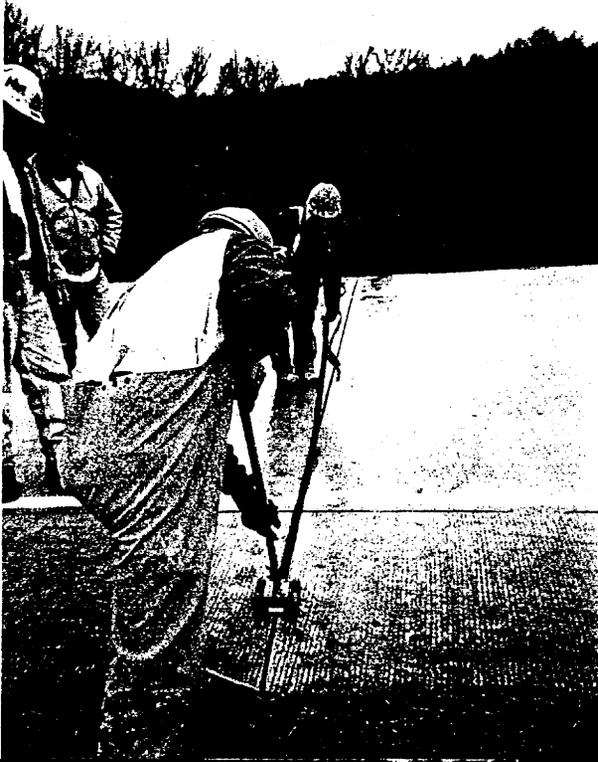
The Expansion Joints need to be blown clean of debris and adhesive should be applied to the internal surfaces of the sawed joint to permit installation of the W-Seal into the joint opening. W-050 Pavement Seal is made of Santoprene thermoplastic and is co-extruded with a stiff plastic to eliminate any stretching during improper installation. Because the W-Seal is "stretch-proof", a simple tool can be used to simplify the installation.



W-050 is laid out across the roadway parallel to the joint opening. The seal is fed through the head of the installation tool and then inserted into the open joint at an end of the pavement. The seal is then secured to prevent slippage with vice grips. The seal can then be installed using the hand tool.

# W-SEAL Pavement Installation, November 1997

page 3



Starting at the "secured" end, apply downward force on the handle of the installation tool. This downward pressure assures that its "installation head" does not lift from the surface as the W-Seal feeds through and properly positions itself in the joint opening.



Continue across the road and maintain a even downward pressure and continuous walking pace as the seal feeds through the tool into the sawed joint opening.

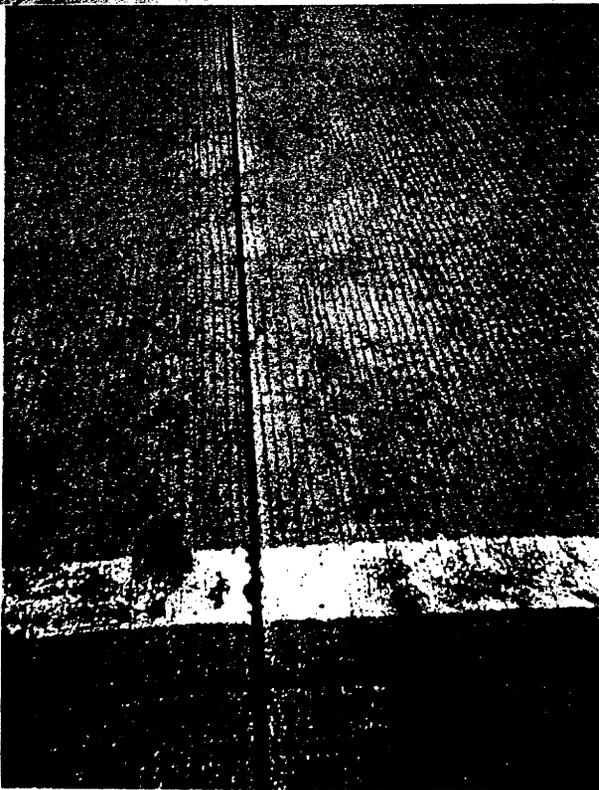
## W-SEAL Pavement Installation, November 1997

page 4



Continue across the roadway. When the end of the roadway is reached the seal should be cut and run out through the tool.

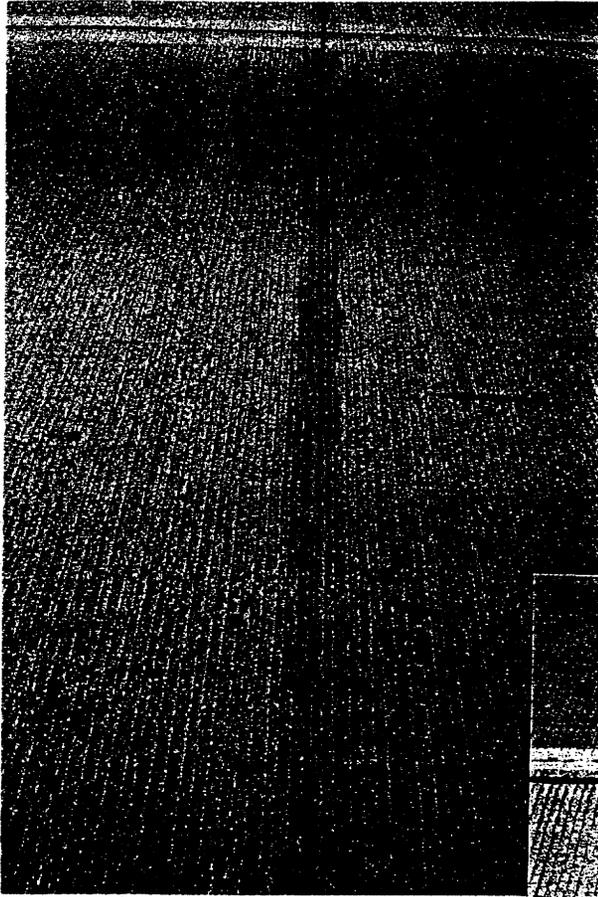
The seal is now installed. Run the tool over the joint once with the seal already installed. This will push down on the W-Seal to assure it is below grade level by eliminating any high points in the seal.



The W-Seal is now completely installed and attention can be directed to the next sawed joint to receive the seal. The adhesive used is a single component urethane requiring mixing of 4 parts adhesive with 1 part water prior to usage. Mixing requires several minutes of significant agitation and has a 20 minute pot life. Adhesive should be mixed as required to assure no spoilage.

## W-SEAL Pavement Inspection, August 1998

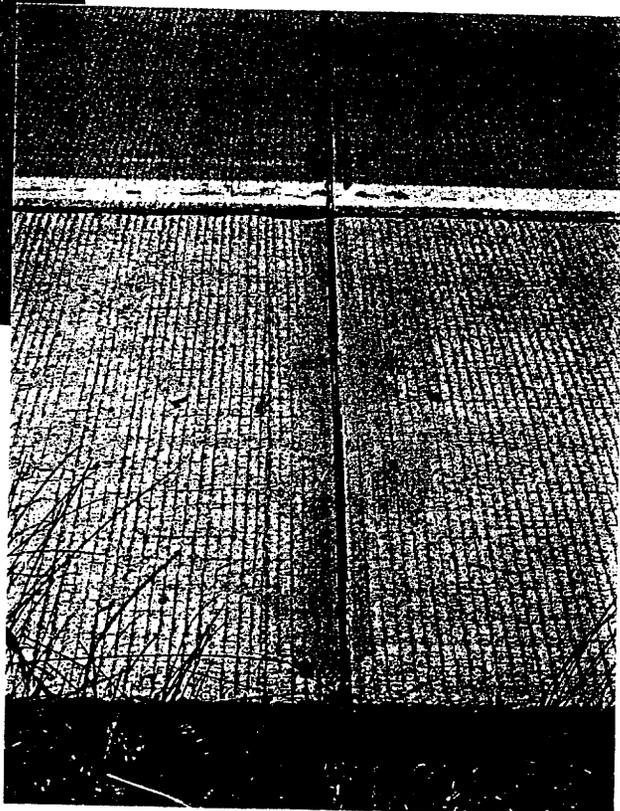
page 5



A inspection was made of the TechStar W-Seal Pavement seal joints on August 20, 1998. 30 joints were installed with TechStar W-050 pre-formed seal. The location of the joints is at the end of the 1st Neoprene compression seal section (going Eastbound) & immediately before the section with open joints.

The W-Seal joints appear to be functioning excellently. The seal was installed at the correct elevation, being slightly below grade and in every joint except the last one (next to the open joints) had a top coating of adhesive as recommended for installation.

The W-Seal operates closer to the surface of the pavement than either the Neoprene seals or the silicone material. This minimizes the ability of large stones entering the joint opening above the seal and creating spalls when during joint closing.





HARRIS SPECIALTY CHEMICALS, INC.

P R O D U C T

*Watson  
Bowman  
Acme*

**DATA**

**WABO®  
COMPRESSION  
SEAL  
PRODUCT  
DATA**

**A DESCRIPTION**

Wabo® Compression Seals feature an internal elastomeric cross sectional web design which exerts pressure to the side walls and, therefore, effectively seals the expansion joint. Wabo® Compression Seals are installed with a lubricant adhesive and are designed to provide a watertight seal and reject incompressibles. Wabo® Compression Seals are recommended for sealing expansion joints in bridges, roadways, parking decks, buildings, water treatment plants, airfields, along with a variety of additional applications.

**B FEATURES**

**1. Material Composition**

Wabo® Compression Seals are made of the highest quality neoprene and are, therefore, highly resistant to deterioration from exposure to weather, sunlight, oils, chemicals, heat, abrasion and impact.

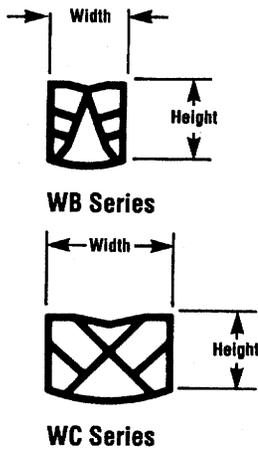
**2. Watertightness**

The unique design of Wabo® Compression Seals allow them to exert a continuous and uniform force against the joint side walls, enabling them to accommodate any variation in joint width while preserving a watertight seal.

Refer to the Wabo® Compression Seal Specification and Installation Data Sheets for additional information on adhesives, installation procedures and system specifications.

## 2. WB and WC Series

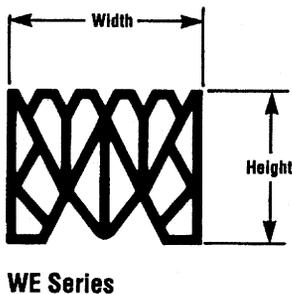
The WB and WC series are specifically designed for concrete pavement and low stress applications. These seals handle movement requirements up to .975 inch. (25mm).



<b>DIMENSION TABLE</b>							
MODEL NO.	MOVEMENT **	WIDTH	HEIGHT	GROOVE WIDTH "A"		GROOVE DEPTH "B"	INSTALLATION WIDTH
				MIN	MAX.		
WB 437	<b>207</b> 5	<b>438</b> 11	<b>.563</b> 14	<b>.153</b> 4	<b>.360</b> 9	<b>1.000</b> 25	<b>.250</b> 6
WB-562	<b>.253</b> 6	<b>.563</b> 14	<b>.688</b> 17	<b>.197</b> 5	<b>.450</b> 11	<b>1.125</b> 29	<b>.313</b> 8
WB-687	<b>.310</b> 8	<b>.688</b> 17	<b>.688</b> 17	<b>.240</b> 6	<b>.550</b> 14	<b>1.250</b> 32	<b>.375</b> 10
WB-812	<b>.365</b> 9	<b>.813</b> 21	<b>.875</b> 22	<b>.284</b> 7	<b>.650</b> 17	<b>1.500</b> 38	<b>.438</b> 11
WB-1000	<b>.450</b> 11	<b>1.000</b> 25	<b>1.125</b> 29	<b>.350</b> 9	<b>.800</b> 20	<b>1.750</b> 44	<b>.500</b> 13
WB-1250	<b>.563</b> 14	<b>1.250</b> 32	<b>1.125</b> 29	<b>.437</b> 11	<b>1.000</b> 25	<b>2.000</b> 51	<b>.625</b> 16
WC-1250	<b>.563</b> 14	<b>1.250</b> 32	<b>1.156</b> 29	<b>.437</b> 11	<b>1.000</b> 25	<b>2.000</b> 51	<b>.625</b> 16
WC-1625	<b>.732</b> 19	<b>1.625</b> 41	<b>1.156</b> 29	<b>.568</b> 14	<b>1.300</b> 33	<b>2.000</b> 51	<b>.750</b> 19
WC-1750	<b>.919</b> 23	<b>2.000</b> 51	<b>1.344</b> 34	<b>.568</b> 14	<b>1.487</b> 38	<b>2.000</b> 51	<b>.875</b> 22
WC-2000	<b>.975</b> 25	<b>2.000</b> 51	<b>1.656</b> 42	<b>.625</b> 16	<b>1.600</b> 41	<b>2.000</b> 51	<b>1.000</b> 25

## 3. WE Series

The WE series are low height joints designed for low stress applications where pedestrian traffic is anticipated. These seals handle movement requirements up to 2.850 inches. (72mm).



<b>DIMENSION TABLE</b>							
MODEL NO.	MOVEMENT **	WIDTH	HEIGHT	GROOVE WIDTH "A"		GROOVE DEPTH "B"	INSTALLATION WIDTH
				MIN	MAX.		
WE-225	<b>1.040</b> 26	<b>2.250</b> 57	<b>1.500</b> 38	<b>.875</b> 22	<b>1.912</b> 49	<b>2.000</b> 51	<b>1.000</b> 25
WE-250	<b>1.065</b> 27	<b>2.500</b> 64	<b>2.000</b> 51	<b>1.060</b> 27	<b>2.125</b> 54	<b>2.375</b> 60	<b>1.500</b> 38
WE-300	<b>1.125</b> 29	<b>3.000</b> 76	<b>2.156</b> 55	<b>1.425</b> 36	<b>2.550</b> 65	<b>2.531</b> 64	<b>2.000</b> 51
WE-400	<b>1.650</b> 42	<b>4.000</b> 102	<b>2.813</b> 71	<b>1.750</b> 44	<b>3.400</b> 86	<b>3.188</b> 81	<b>2.375</b> 60
WE-500	<b>2.125</b> 54	<b>5.000</b> 127	<b>3.250</b> 83	<b>2.125</b> 54	<b>4.250</b> 108	<b>3.625</b> 92	<b>2.875</b> 73
WE-600	<b>2.850</b> 72	<b>6.000</b> 152	<b>4.000</b> 102	<b>2.250</b> 57	<b>5.100</b> 130	<b>4.625</b> 117	<b>3.500</b> 89

\*\* Different methods and specifications are often used when determining joint movements. Please contact your Watson Bowman Acme Representative to determine actual seal size for your particular need.

## **WABO COMPRESSION SEAL SPECIFICATION**

### **A. GENERAL**

This work shall consist of fabricating, furnishing and installing a bridge expansion joint device of the type shown on the plans, at the location shown on the plans, and in accordance with these specifications. The bridge expansion joint device shall seal the deck surface, gutters, curbs and parapets as indicated on the plans, and prevent water from seeping through the joint area. The Contractor shall state at the preconstruction conference the specific manufacturer and model number of the device he intends to furnish and install. Expansion joint device manufacturer shall be pre-qualified with a five year proven history of successful product manufacture and have A.I.S.C. Category III and/or C.W.B. shop approval.

The preformed elastomeric joint seal shall accommodate the movements indicated on the contract drawings.

### **B. DEFINITION**

#### **1. Preformed Elastomeric Joint Seal**

The preformed virgin polychloroprene elastomeric joint seal shall feature a multiple-web design which exerts pressure to the side walls. The seal is designed to seal the joint and reject incompressibles.

All materials shall be as specified in the contract documents or as recommended by the supplier of the preformed elastomeric joint seal. The preformed elastomeric joint seal shall be referred to throughout this specification as the joint seal.

### **C. MATERIALS**

The Contractor shall furnish a supplier's certification that the materials proposed for use on the project have been pretested and will meet the requirements as set forth in the supplier's current literature.

The supplier shall verify that the following components meet the list requirements.

#### **1. Continuous Preformed Polychloroprene Elastomeric Joint Seal**

The polychloroprene seal shall be supplied and installed in one continuous length. The shape of the gland shall promote self-removal of foreign material during normal joint operation. Requirements of the preformed polychloroprene elastomeric joint seal shall be in conformance with ASTM Specification D3542-83. The physical properties shall be in accordance with Table 1.

**TABLE 1: Physical Requirements For Preformed Elastomeric Joint Seals**

<b>PHYSICAL PROPERTY</b>	<b>ASTM TEST METHOD</b>	<b>REQUIREMENTS</b>
Tensile Strength, min.,MPa	D-412	13.8 MPa
Elongation @ break, min, %	D-412	250
Hardness, Type A Durometer, points	D-2240 Modified	55 +/-5
Oven aging, 70h @ 100°C	D-573	
Tensile strength, max, % loss		20
Elongation, max, % loss		20
Hardness, Type A Durometer, points change		0 to + 10
Oil Swell, ASTM Oil No.3, 70h @ 100°C	D-471	
Weight change, max, %		45
Ozone resistance	D-1149	no cracks
20% strain, 300 pphm in air	Modified	
70h @ 40°C		
Low temperature stiffening,	D-2240	
7 days @ -10°C		
Hardness, Type a Durometer, points change		0 to + 15
Compression Set,	D-395	40%
70h @ 100°C max.	Method B (modified)	

2. Lubricant Adhesive

The material used in bonding the preformed polychloroprene elastomeric joint seal shall be a one part moisture curing polyurethane and hydrocarbon solvent mixture meeting the requirements of ASTM D-4070-81.

**D. CONSTRUCTION REQUIREMENTS**

The Contractor shall submit shop drawings in a timely fashion, after the award of contract. The joint seal shall be accurately set and installed at the correct grade and elevation and the correct joint opening as shown on the plans and on the shop drawings.

**E. METHOD OF MEASUREMENT**

The work will be measured as the number of linear metres of joint seal completely installed. Measurement will be taken horizontally and vertically along the centerline of the joint system between the outer limits indicated on the Contract Plans. The words "completely installed" shall be interpreted to mean the joint seal in place with the following operations completed:

1. Concrete placed and finished
2. Epoxy mortar placed and finished

COMPRESSION SEAL

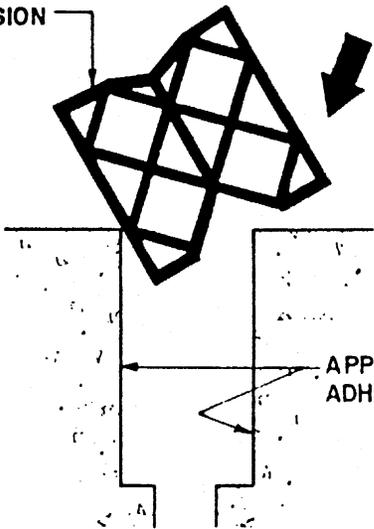


FIGURE 1

POGO STICK (INSTALLATION TOOL)

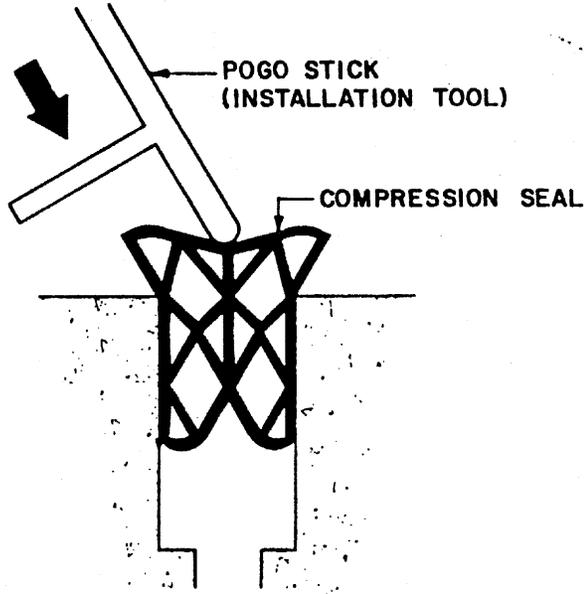


FIGURE 2

COMPRESSION SEAL

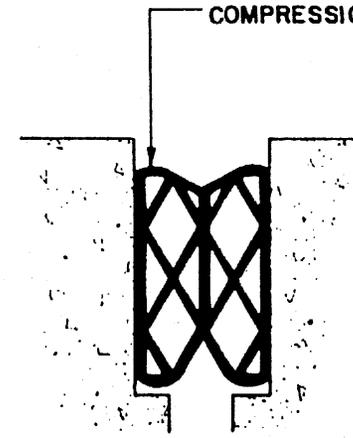


FIGURE 3

ONCE THE JOINT GROOVE IS COMPLETED BY FORMING OR SAWING, THE COMPRESSION SEAL IS THEN INSTALLED.

THE FOLLOWING PROCEDURES WILL MINIMIZE SEAL FAILURES AND INCREASE THE EASE OF INSTALLATION:

1. CLEAN DIRT, STONES OR STANDING WATER FROM JOINT USING A BRUSH OR COMPRESSED AIR.
2. APPLY BONLASTIC ADHESIVE BY BRUSH, SPATULA OR SPRAY EQUIPMENT TO EACH INNER JOINT FACE.
3. POSITION WABO COMPRESSION SEAL OVER THE JOINT AS SHOWN ABOVE.
4. COMPRESS BOTTOM PORTION OF WABO COMPRESSION SEAL AND INSERT INTO JOINT AS SHOWN.
5. COMPLETE INSTALLATION BY POSITIONING WABO COMPRESSION SEAL WITHIN THE JOINT TO A DEPTH REQUIRED BY THE APPLICATION INVOLVED.

NAME  
REVISION DESCRIPTION  
NO. DATE



95 Powers Place, Anderson, N.Y. 14120      17161 691 756E      P.O. Box 51 Getzville, N.Y. 14068

PROJECT		
<b>INSTALLATION PROCEDURE</b>		
TITLE <b>COMPRESSION SEAL</b>		
DETAILED BY <b>D. STEIGER</b>	DATE <b>2-26-87</b>	SCALE <b>NTS</b>
CHECKED BY	DATE	DRAWING NUMBER
SHEET NO	JOB NO	<b>B-9574</b>

DRAWING NO. WABO 14068-0



## **APPENDIX C**

### **Profilometer Information and Data**

☛ **Inertial Profilometer Model 690DNC**

☛ **Output from Profilometer Runs**



# INERTIAL PROFILOMETER<sup>®</sup>

## MODEL 690DNC

The Model 690DNC is a very accurate and repeatable, non-contact computer-based system which measures and records pavement profiles for highways, runways, or test tracks at speeds between 10 and 70 MPH (20 KPH-110 KPH). Using a patented, spatially-based processing method, pavement profiles are produced unaffected by variations in vehicle weight, speed, extremes in ambient air temperature, or pavement color and texture.

Profiles are measured in real time by a non-contact optical displacement measuring system and precision accelerometers in the right and left wheel paths. The accelerometers measure vehicle motion while the

optical measuring system measures displacement between the vehicle body and the paved surface. These two inputs are fed into the system's on-board microcomputer which computes the road profile.

Pavement profile data points, taken every two inches, are averaged over a running twelve inch interval\* and are stored as profile points on magnetic tape for every six inches of travel (displacement resolution is 0.010 inches [0.25 mm]). System outputs, including pavement profiles, can be displayed on the color graphics monitor, copied on the graphics printer, downloaded from magnetic tape to a central computer, or used simultaneously for the determination

of real time Response Type Ride Roughness Meters (RTRRM's) roughness indexes using a quarter car simulator program (Golden Car parameters).

The Model 690DNC meets the requirements of ASTM Standard E950 and has been purchased by the FHWA for AASHTO's AMRL and to calibrate RTRRM's. The system computes the Present Serviceability Index (PSI), or other indexes, based on RTRRM systems such as Root-Mean Square Acceleration (RMSA) index (ISO method), Mays Ride Meter (MRM), International Ride Index (IRI), PCA or COX Roadmeter, etc. One of the RTRRM-based indexes can be printed several times per mile (normalized to "inches per mile") or simulated later from the recorded profiles. A number of optional pavement management programs such as Bituminous Fill, Mill/Grind/Fill, and profile related programs like Rut Depth, Slab Fault, and Cross-Slope are available.

\*Anti-Aliasing technique.

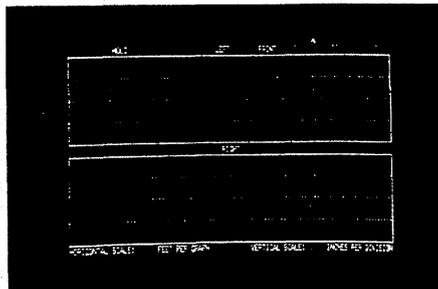
**K.J. LAW**  
**ENGINEERS, INC.**

# M O D E L 6 9 0 D N C



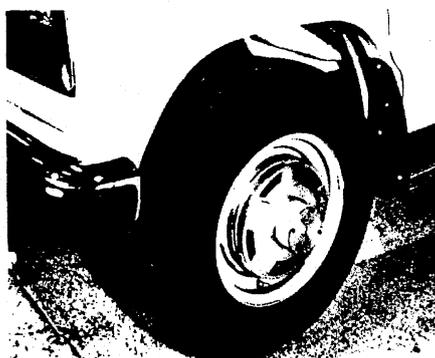
## Operator's Station

Includes color graphics monitor to view recorded graphs of road profiles, and a data entry keyboard.



## Color Graphics Monitor

This displays the computed profile measurement signals for the left and right wheel paths. Amplitude and distance scaling of measured profiles are selected prior to the measuring run and/or profile re-display runs.



## Digital Distance Encoder

This provides the digital pulse signals to clock the system's computer which computes accurate profiles, distance traveled, and vehicle test speed.



## Non-Contact Measuring System

Dual Model 3000 light beam non-contact vehicle-to-road displacement sensors and vertical vehicle motion servo accelerometers are used to accurately produce a profile. (A third sensor and cross-slope gyroscope are optional for rut depth and cross-slope measurements.) A photocell pickup is used to accurately start and stop profile measurements using reflective markings on the road surface.



## Interior Instrumentation

A microcomputer, magnetic tape drive, dual 5 1/4" floppy disk drives, hard drive, graphics printer, and K. J. Law Engineers, Inc. Model 3000 Displacement Signal Processing Instrument are standard equipment.

## S P E C I F I C A T I O N S

- Test Principle:** Longitudinal Profile Computed from Optical Displacement Measurement using an Inertial Reference Plane
- Test Vehicle:** Ford Model F250 3/4 Ton Van
- Computer:** Digital Equipment Corporation Micro
- DEC Color Graphics Monitor
  - DEC Magnetic Tape Drive
  - DEC Dual (5 1/4") Floppy Disk Drive
  - DEC Hard Drive
  - DEC Keyboard
  - DEC Graphics Printer
- Instrumentation:** K. J. Law Engineers, Inc.
- Model 3000 Displacement Signal Processing Instrument
  - Light Beam Sensors (third sensor optional)
  - Precision Accelerometers
  - Cross-slope Gyroscope (optional)
  - Photocell Pickup

**K. J. LAW**  
**ENGINEERS, INC.**

23660 Research Drive, Farmington Hills, Michigan 48024, U.S.A.  
Michigan customers, call (313) 478-3150; Outstate, call (800) 521-5245  
Telex: 23-1179; FAX: (313) 478-5610

Printed in U.S.A.  
MFB985000

ATH050R  
10JUN98  
K.J. Law Profilometer  
Model 690DNC

Run 1 Up

Run 2 Up

Run 3 Up

ATHUSB.002

ATHUSD.004

ATHUSF.006

Station	Miles	MAYS	PSI	IRIlf	IRIrt	IRIbh	MAYS	PSI	IRIlf	IRIrt	IRIbh	MAYS	PSI	IRIlf	IRIrt	IRIbh
15400.0	0.00															
15452.8	0.01	38.7	4.132	19.0	75.9	47.5	38.8	4.095	16.3	79.1	47.7	43.9	4.051	13.4	86.4	49.9
15505.6	0.02	47.3	4.068	38.9	77.5	58.2	47.6	4.089	35.5	76.8	56.2	44.5	4.117	32.3	71.4	51.9
15558.4	0.03	38.9	4.280	46.3	56.5	51.4	35.1	4.280	43.5	53.7	48.6	36.2	4.288	43.7	53.9	48.8
15611.2	0.04	62.2	3.869	46.7	102.7	74.7	61.0	3.878	48.2	101.8	75.0	63.5	3.829	46.7	105.0	75.9
15664.0	0.05	44.2	4.027	36.4	87.4	61.9	46.5	4.092	34.5	88.4	61.4	47.7	4.021	31.7	90.0	60.8
15716.8	0.06	62.7	4.244	91.6	62.5	77.0	56.8	4.326	88.0	62.1	75.0	61.5	4.191	81.4	69.3	75.3
15769.6	0.07	39.1	4.205	34.6	71.4	53.0	41.6	4.057	44.3	81.3	62.8	40.3	4.185	34.0	73.7	53.8
15822.4	0.08	29.8	4.402	35.0	47.3	41.2	28.9	4.391	35.7	48.6	42.1	27.8	4.422	33.1	52.1	42.6
15875.2	0.09	32.8	4.308	30.8	53.3	42.0	33.4	4.302	36.1	52.9	44.5	30.0	4.332	30.1	50.9	40.5
15928.0	0.10	24.8	4.426	27.4	41.7	34.6	27.3	4.406	29.2	45.8	37.5	25.9	4.460	17.1	47.1	32.1
15980.8	0.11	46.1	4.199	41.0	71.1	56.1	44.8	4.168	40.8	70.7	55.8	43.2	4.273	47.2	65.1	56.1
16033.6	0.12	42.9	4.172	40.1	72.2	56.1	42.5	4.175	36.3	73.6	54.9	40.0	4.181	27.8	71.2	49.5
16086.4	0.13	33.6	4.294	33.8	53.3	43.6	34.8	4.300	36.0	58.3	47.1	28.7	4.416	34.0	51.1	42.6
16139.2	0.14	34.6	4.293	36.6	57.4	47.0	34.9	4.311	36.3	58.4	47.4	36.7	4.339	39.1	53.2	46.2
16192.0	0.15	37.0	4.245	29.1	57.2	43.1	35.7	4.360	30.3	57.2	43.7	34.3	4.351	26.4	56.3	41.3
16244.8	0.16	31.0	4.361	34.9	47.3	41.1	31.7	4.388	31.2	49.1	40.1	31.1	4.398	31.8	45.5	38.7
16297.6	0.17	27.8	4.347	37.9	52.7	45.3	27.5	4.414	40.4	52.2	46.3	27.3	4.391	36.3	50.3	43.3
16350.4	0.18	44.7	4.249	55.6	72.4	64.0	46.2	4.280	51.9	71.1	61.5	42.7	4.247	50.8	69.8	60.3
16403.2	0.19	32.1	4.431	31.2	46.0	38.6	29.0	4.472	28.9	45.1	37.0	31.1	4.476	24.9	49.6	37.2
16456.0	0.20	35.1	4.262	36.6	59.2	47.9	37.6	4.287	35.5	62.2	48.9	33.7	4.355	35.2	59.3	47.2
16508.8	0.21	32.6	4.412	26.3	52.7	39.5	36.5	4.304	30.0	60.6	45.3	35.2	4.375	33.3	55.0	44.2
16561.6	0.22	45.1	4.209	56.4	77.3	66.8	46.3	4.205	54.2	74.3	64.3	44.5	4.208	54.3	76.8	65.6
16614.4	0.23	29.0	4.486	38.0	46.7	42.4	30.6	4.451	38.3	53.6	46.0	33.4	4.395	35.5	53.8	44.7
16667.2	0.24	51.1	4.084	30.4	94.5	62.4	48.9	4.122	30.9	88.2	59.6	47.7	4.094	33.7	90.4	62.1
16720.0	0.25	27.1	4.410	22.3	51.4	36.9	25.3	4.472	23.5	46.7	35.1	30.7	4.320	21.8	57.2	39.5
16772.8	0.26	26.6	4.427	23.6	50.0	36.8	28.7	4.399	23.2	54.1	38.6	28.7	4.394	20.5	52.8	36.6
16825.6	0.27	27.6	4.377	36.6	44.7	40.6	30.0	4.350	32.0	48.7	40.3	23.9	4.437	29.2	40.6	34.9
16878.4	0.28	57.8	4.081	63.2	85.2	74.2	56.7	4.066	64.0	87.5	75.8	58.7	4.002	64.6	91.3	78.0
16931.2	0.29	54.5	4.220	57.9	74.0	66.0	47.1	4.352	47.4	66.9	57.1	51.3	4.255	51.7	72.9	62.3
16984.0	0.30	50.3	4.429	69.6	58.7	64.2	48.7	4.433	62.0	60.1	61.1	51.6	4.369	67.6	65.2	66.4
17036.8	0.31	51.7	4.280	71.1	71.9	71.5	55.6	4.241	72.1	77.3	74.7	53.1	4.236	66.2	74.9	70.6
17089.6	0.32	65.6	4.290	80.0	70.4	75.2	66.8	4.313	87.7	70.1	78.9	64.1	4.342	85.3	70.7	78.0
17142.4	0.33	69.1	4.370	100.4	68.1	84.3	72.1	4.337	108.0	67.5	87.7	69.0	4.335	104.0	65.7	84.8
17195.2	0.34	44.3	4.210	43.2	65.0	54.1	39.6	4.233	34.4	62.3	48.3	39.8	4.236	34.5	64.9	49.7
17248.0	0.35	44.7	4.450	56.4	49.1	52.8	43.0	4.473	55.8	49.0	52.4	47.3	4.436	61.4	46.8	54.1
17300.8	0.36	46.4	4.300	55.7	58.3	57.0	44.0	4.390	53.2	49.0	51.1	45.9	4.285	52.4	57.9	55.1
17353.6	0.37	36.8	4.272	39.3	70.6	54.9	33.5	4.316	38.6	59.3	49.0	41.2	4.262	39.1	69.6	54.4
17406.4	0.38	33.6	4.374	40.5	55.6	48.1	30.8	4.366	32.0	53.5	42.8	29.8	4.441	33.4	53.6	43.5

17459.2	0.39	45.9	4.209	37.7	96.0	66.8	41.5	4.252	36.7	93.3	65.0	42.4	4.272	35.5	93.6	64.6
17512.0	0.40	35.5	4.380	52.3	69.7	61.0	30.3	4.430	50.9	56.9	53.9	29.4	4.466	53.1	55.1	54.1
17564.8	0.41	62.2	4.190	65.6	77.4	71.5	59.8	4.250	66.2	71.3	68.8	58.8	4.333	63.8	67.6	65.7
17617.6	0.42	49.6	4.234	58.4	79.5	68.9	44.0	4.296	52.8	75.2	64.0	48.6	4.261	53.9	75.4	64.6
17670.4	0.43	41.1	4.179	27.5	74.6	51.0	39.5	4.228	27.4	67.1	47.2	40.8	4.216	31.6	66.5	49.0
17723.2	0.44	37.7	4.397	57.3	64.2	60.7	36.4	4.450	59.8	59.2	59.5	38.2	4.443	61.0	62.7	61.9
17776.0	0.45	42.2	4.235	38.7	70.1	54.4	45.3	4.224	41.3	68.8	55.1	43.6	4.229	39.7	68.0	53.8
17828.8	0.46	35.5	4.365	40.1	52.7	48.4	38.0	4.414	44.9	57.2	51.0	39.3	4.351	42.8	61.6	52.2
17881.6	0.47	49.5	4.109	41.7	84.7	63.2	46.6	4.169	35.7	76.0	55.9	48.8	4.147	40.5	73.4	56.9
17934.4	0.48	36.1	4.323	39.7	50.0	44.8	30.1	4.485	36.0	46.4	41.2	32.6	4.492	41.8	46.6	44.2
17987.2	0.49	29.8	4.544	40.4	41.4	40.9	31.6	4.522	42.2	50.6	46.4	31.1	4.546	45.6	44.3	44.9
18040.0	0.50	34.9	4.447	48.7	50.6	49.6	34.0	4.331	48.3	61.5	54.9	29.7	4.452	40.8	51.2	46.0
18092.8	0.51	50.5	4.212	51.9	100.9	76.4	53.3	4.212	46.3	94.5	70.4	52.5	4.179	46.7	93.6	70.1
18145.6	0.52	36.5	4.305	35.0	56.4	45.7	35.9	4.275	41.8	69.8	55.8	31.6	4.333	33.1	66.1	49.6
18198.4	0.53	39.1	4.417	41.5	53.1	47.3	36.0	4.456	57.5	59.1	58.3	31.1	4.489	46.4	55.1	50.7
18251.2	0.54	47.5	4.230	49.5	62.8	56.2	39.0	4.401	55.4	62.0	58.7	42.1	4.444	67.9	55.9	61.9
18304.0	0.55	43.8	4.047	39.9	67.4	53.7	42.4	4.470	53.8	57.3	55.5	39.9	4.322	46.7	65.0	55.9
18356.8	0.56	39.9	4.292	31.7	60.0	45.9	35.0	4.247	19.5	62.8	41.1	31.7	4.365	17.5	57.1	37.3
18409.6	0.57	49.6	4.365	48.8	62.6	55.7	41.4	4.439	44.8	62.3	53.6	38.6	4.404	44.7	57.0	50.8
18462.4	0.58	56.1	4.322	72.9	60.2	66.5	65.4	4.255	85.5	61.8	73.6	63.2	4.315	83.8	57.2	70.5
18515.2	0.59	85.6	4.056	97.2	100.3	98.7	94.2	4.123	128.5	96.6	112.6	93.5	4.127	127.3	92.4	109.8
18568.0	0.60	62.6	4.249	73.0	69.7	71.3	75.2	4.339	102.1	66.6	84.3	74.2	4.349	104.2	68.1	86.1
18620.8	0.61	63.7	4.225	72.2	83.7	78.0	65.5	4.339	88.0	75.1	81.6	65.2	4.235	84.2	84.3	84.2
18673.6	0.62	57.1	4.249	81.3	78.1	79.7	57.0	4.376	72.3	68.3	70.3	55.4	4.276	82.0	81.8	81.9
18726.4	0.63	43.2	4.218	73.2	87.3	80.3	46.1	4.249	60.1	90.7	75.4	49.6	4.147	64.9	94.3	79.6
18779.2	0.64	55.7	4.129	79.8	85.7	82.7	47.9	4.305	64.6	64.0	64.3	53.6	4.120	66.5	88.8	77.6
18832.0	0.65	24.4	4.475	34.8	40.5	37.7	30.1	4.539	37.5	40.3	38.9	26.3	4.523	31.5	38.4	34.9
18884.8	0.66	40.9	4.376	67.5	56.0	61.7	38.1	4.486	66.7	46.4	56.5	38.7	4.485	63.8	55.0	59.4
18937.6	0.67	46.2	4.338	50.1	57.0	53.6	38.6	4.390	43.0	53.8	48.4	40.6	4.387	42.1	56.3	49.2
18990.4	0.68	33.8	4.416	47.3	42.4	44.9	30.3	4.512	43.5	45.3	44.4	29.8	4.459	43.9	44.7	44.3
19043.2	0.69	77.8	4.398	106.1	74.4	90.2	74.4	4.399	97.8	73.6	85.7	71.4	4.390	98.8	74.9	86.8
19096.0	0.70	55.8	4.268	74.6	68.5	71.6	55.4	4.218	72.2	67.8	70.0	60.9	4.182	81.3	74.4	77.9
19148.8	0.71	40.0	4.435	57.7	64.3	61.0	37.7	4.434	46.7	69.4	58.1	45.7	4.306	60.9	78.8	69.9
19201.6	0.72	22.8	4.485	51.4	54.9	53.2	24.5	4.462	46.5	53.7	50.1	26.8	4.383	50.7	54.7	52.7
19254.4	0.73	28.3	4.405	43.8	68.0	55.9	33.4	4.369	45.9	71.4	58.6	35.5	4.240	41.9	82.9	62.4
19307.2	0.74	51.5	4.162	57.0	73.1	65.0	44.6	4.367	54.3	56.5	55.4	52.2	4.051	48.3	92.3	70.3
19360.0	0.75	37.5	4.276	34.5	60.0	47.3	38.0	4.259	29.9	65.1	47.5	37.2	4.194	34.1	61.6	47.8
19412.8	0.76	71.4	4.255	81.2	86.9	84.0	70.9	4.252	74.4	84.9	79.7	74.6	4.127	81.5	86.9	84.2
19465.6	0.77	66.1	4.235	66.7	86.5	76.6	56.0	4.273	53.4	81.4	67.4	62.8	4.191	65.9	83.0	74.4
19518.4	0.78	29.1	4.372	35.2	55.3	45.3	33.6	4.309	39.0	59.5	49.2	36.5	4.311	34.0	71.7	52.9
19571.2	0.79	32.5	4.364	41.5	61.0	51.3	33.9	4.282	41.3	61.9	51.6	28.8	4.344	41.0	57.4	49.2
19624.0	0.80	34.7	4.399	45.5	55.8	50.7	32.3	4.407	52.9	50.0	51.4	33.9	4.423	43.8	54.1	49.0
19676.8	0.81	47.0	4.444	63.3	53.5	58.4	46.5	4.372	55.4	60.4	57.9	50.9	4.359	64.5	58.8	61.6
19729.6	0.82	45.2	4.182	38.0	78.7	58.3	42.9	4.187	40.9	74.3	57.6	44.6	4.237	38.7	78.9	58.8
19782.4	0.83	26.1	4.372	16.3	52.7	34.5	27.1	4.342	24.4	52.0	38.2	29.2	4.336	14.6	60.4	37.5
19835.2	0.84	49.1	4.058	45.4	80.5	63.0	48.5	4.053	44.1	73.6	58.8	49.8	4.079	47.9	77.3	62.6
19888.0	0.85	55.6	4.342	69.1	57.0	63.0	49.0	4.298	61.5	53.8	57.7	55.2	4.216	69.3	61.9	65.6
19940.8	0.86	87.1	4.178	96.0	89.3	92.7	84.5	4.188	98.7	82.9	90.8	87.6	4.212	102.4	89.1	95.7
19993.6	0.87	55.7	4.417	73.4	62.5	67.9	57.0	4.284	56.1	74.0	65.1	63.0	4.239	72.0	79.4	75.7
20046.4	0.88	41.8	4.337	49.6	60.3	54.9	42.4	4.357	50.0	59.4	54.7	40.1	4.414	45.4	59.3	52.4
20099.2	0.89	43.2	4.105	36.5	83.0	59.8	53.4	3.991	49.1	95.2	72.2	50.5	4.001	38.4	99.4	68.9
20152.0	0.90	49.4	4.338	51.0	58.4	54.7	44.3	4.278	44.3	54.5	49.4	46.8	4.359	52.1	51.4	51.8
20204.8	0.91	65.4	4.036	69.6	100.2	84.9	64.7	3.925	67.3	103.0	85.1	57.5	4.051	66.7	98.4	82.5
20257.6	0.92	54.4	4.117	54.4	87.9	71.1	51.7	4.040	41.2	90.2	65.7	54.7	4.183	43.3	86.3	64.8
20310.4	0.93	68.5	4.024	63.7	95.2	79.5	74.6	3.938	63.7	102.8	83.2	68.5	4.115	68.7	91.6	80.1

20363.2	0.94	53.2	4.095	43.8	84.4	64.1	55.9	4.006	47.5	88.4	68.0	56.4	4.063	42.4	91.6	67.0
20416.0	0.95	41.7	4.297	57.3	67.0	62.1	37.7	4.300	49.1	61.0	55.1	32.4	4.371	45.9	54.8	50.3
20468.8	0.96	30.9	4.342	35.2	52.0	43.6	31.8	4.323	34.9	53.9	44.4	34.2	4.264	33.4	61.0	47.2
20521.6	0.97	52.0	4.062	45.7	90.7	68.2	50.5	4.070	39.7	88.8	64.3	55.0	4.029	45.2	93.6	69.4
20574.4	0.98	39.3	4.384	52.5	57.1	54.8	44.2	4.292	54.4	63.6	59.0	35.7	4.401	52.6	53.7	53.1
20627.2	0.99	32.4	4.505	52.1	39.8	45.9	36.0	4.419	53.1	45.8	49.4	33.1	4.517	53.1	37.4	45.3
20680.0	1.00	32.8	4.566	35.9	46.8	41.3	33.9	4.498	38.8	49.2	44.0	35.2	4.552	40.3	45.9	43.1
20732.8	1.01	38.6	4.395	35.0	64.8	49.9	38.1	4.357	36.2	62.4	49.3	38.9	4.428	30.4	63.7	47.1
20785.6	1.02	81.3	4.433	92.9	57.3	75.1	63.1	4.306	92.9	60.0	76.5	60.3	4.354	87.7	59.7	73.7
20838.4	1.03	48.6	4.322	56.9	73.1	65.0	48.3	4.422	60.7	60.9	60.8	46.4	4.475	57.2	53.7	55.4
20891.2	1.04	81.9	4.315	107.2	71.7	89.5	79.9	4.364	100.4	69.0	84.7	79.3	4.365	99.9	67.3	83.6
20944.0	1.05	33.5	4.537	53.1	50.1	51.6	33.7	4.560	49.6	48.8	49.2	33.5	4.589	47.1	42.8	45.0
20996.8	1.06	33.3	4.468	47.0	65.5	56.3	37.2	4.428	40.6	71.2	55.9	35.1	4.446	44.4	68.1	56.2
21049.6	1.07	37.7	4.395	70.2	66.5	63.3	36.6	4.432	59.4	55.4	57.4	35.4	4.413	61.1	53.8	57.5
21102.4	1.08	62.2	4.310	86.5	64.0	75.3	61.0	4.284	81.4	68.2	74.8	55.9	4.204	72.1	63.6	67.9
21155.2	1.09	64.4	4.499	82.2	77.4	79.8	64.1	4.460	84.3	72.0	78.2	65.5	4.482	84.8	73.3	79.0
21208.0	1.10	36.0	4.467	43.1	59.4	51.3	34.0	4.525	36.6	49.2	43.9	32.4	4.407	34.5	64.4	49.4
21260.8	1.11	39.6	4.508	54.5	50.6	52.5	40.2	4.519	51.0	54.6	52.8	40.2	4.507	52.7	46.0	49.3
21313.6	1.12	46.8	4.406	60.5	49.5	55.0	48.3	4.473	65.9	49.2	57.5	48.7	4.402	61.6	51.2	56.4
21366.4	1.13	45.4	4.442	69.6	31.5	50.5	44.3	4.411	57.1	44.3	50.7	39.8	4.464	57.4	40.2	48.8
21419.2	1.14	45.5	4.462	64.3	53.8	59.1	43.6	4.511	59.1	52.9	56.0	45.0	4.472	61.2	49.0	55.1
21472.0	1.15	36.2	4.465	57.4	43.3	50.3	31.7	4.529	49.2	40.3	44.7	45.9	4.452	75.0	46.0	60.5
21524.8	1.16	50.7	4.411	76.4	43.4	59.9	41.8	4.382	72.9	54.7	63.8	34.6	4.434	56.2	43.6	49.9
21577.6	1.17	51.3	4.478	59.2	65.9	62.5	57.4	4.214	70.1	76.8	73.5	53.3	4.480	64.1	60.8	62.4
21630.4	1.18	35.6	4.426	34.5	53.3	43.9	34.9	4.460	37.9	50.6	44.3	25.7	4.505	45.8	48.5	47.1
21683.2	1.19	23.5	4.528	44.7	44.6	44.7	26.2	4.558	37.1	39.6	38.4	34.3	4.504	43.1	40.4	41.8
21736.0	1.20	21.7	4.529	33.1	33.3	33.2	25.3	4.460	32.3	39.0	35.6	31.6	4.391	35.0	49.1	42.0
21788.8	1.21	40.8	4.450	59.1	55.1	57.1	44.1	4.389	65.1	63.0	64.1	34.2	4.521	55.5	47.1	51.3
21841.6	1.22	36.2	4.391	45.7	73.4	59.5	35.2	4.390	45.4	61.3	53.4	34.2	4.426	34.7	60.5	47.6
21894.4	1.23	74.7	4.194	94.7	76.1	85.4	60.5	4.198	73.6	73.5	73.5	71.4	4.195	91.0	77.1	84.0
21947.2	1.24	41.0	4.492	57.8	52.2	55.0	43.3	4.439	48.6	60.6	54.6	39.7	4.365	49.2	57.7	53.4
22000.0	1.25	37.2	4.261	45.7	62.7	54.2	53.5	4.169	66.7	64.9	65.8	39.3	4.223	56.2	69.3	62.7
22052.8	1.26	44.9	4.101	50.6	77.5	64.1	44.4	4.063	37.0	78.7	57.9	55.2	3.990	57.0	85.4	71.2
22105.6	1.27	56.0	4.394	80.2	66.7	73.4	51.0	4.282	50.7	60.7	55.7	55.4	4.360	81.1	67.2	74.1
22158.4	1.28	39.8	4.328	47.1	59.2	53.2	33.9	4.282	50.7	60.7	55.7	35.3	4.350	40.1	58.8	49.4
22211.2	1.29	26.4	4.401	36.9	56.2	46.5	29.2	4.381	49.5	53.0	51.3	26.7	4.383	32.2	51.2	41.7
22264.0	1.30	42.6	4.331	47.8	56.4	53.1	50.3	4.309	62.4	61.7	62.0	45.3	4.395	50.8	63.3	57.0
22316.8	1.31	34.0	4.354	38.0	55.5	46.7	36.9	4.271	36.2	63.5	49.8	30.9	4.392	32.9	54.2	43.5
22369.6	1.32	26.0	4.522	25.9	36.7	31.3	29.1	4.467	30.4	40.3	35.4	23.1	4.529	21.0	36.3	28.6
22422.4	1.33	44.0	4.299	54.9	63.7	59.3	46.6	4.334	66.5	63.1	64.8	47.0	4.237	57.3	70.7	64.0
22475.2	1.34	49.8	4.257	83.1	70.6	76.8	58.4	4.157	92.3	71.6	82.0	47.7	4.264	78.5	69.2	73.9
22528.0	1.35	38.4	4.320	42.3	66.9	54.6	43.1	4.284	43.6	73.7	58.6	36.3	4.285	32.5	69.4	50.9
22580.8	1.36	39.9	4.413	34.6	58.2	46.4	39.5	4.409	36.8	58.5	47.6	41.1	4.409	37.9	57.1	47.5
22633.6	1.37	34.9	4.399	43.1	59.6	51.3	32.5	4.370	39.5	63.0	51.3	32.3	4.294	39.5	66.7	53.1
22686.4	1.38	33.3	4.360	29.9	56.7	43.3	32.1	4.393	21.1	58.4	39.7	37.3	4.276	21.6	69.8	45.7
22739.2	1.39	43.7	4.300	50.7	68.8	59.7	42.5	4.278	44.6	67.9	56.2	40.4	4.370	50.2	58.5	54.3
22792.0	1.40	45.0	4.391	64.2	56.0	60.1	46.0	4.357	62.3	62.3	62.3	42.7	4.344	52.2	63.4	57.8
22844.8	1.41	53.0	4.233	76.4	80.8	78.6	52.9	4.246	81.1	77.4	79.2	48.8	4.231	75.7	78.9	77.3
22897.6	1.42	33.0	4.392	26.2	57.3	41.7	33.4	4.390	29.2	60.4	44.8	32.7	4.368	28.3	58.3	43.3
22950.4	1.43	67.3	4.422	83.3	62.2	72.7	67.0	4.403	81.0	67.3	74.1	64.4	4.421	77.9	62.6	70.3
23003.2	1.44	73.6	4.419	93.1	65.6	79.4	76.0	4.413	89.3	68.4	78.8	73.4	4.454	94.5	63.1	78.8
23056.0	1.45	72.8	4.270	97.0	68.6	82.8	68.2	4.266	91.7	70.5	81.1	73.6	4.294	96.3	68.9	82.6
23108.8	1.46	36.7	4.438	50.8	51.1	50.9	33.0	4.452	41.9	47.3	44.6	33.4	4.433	46.2	52.0	49.1
23161.6	1.47	47.9	4.442	79.6	53.2	66.4	40.2	4.505	71.7	52.1	61.9	44.7	4.418	67.5	52.2	59.8
23214.4	1.48	60.1	3.943	30.0	108.7	69.4	62.6	3.943	39.2	107.2	73.2	60.7	3.948	32.6	110.9	71.8

23267.2	1.49	74.0	4.102	96.4	94.6	95.5	74.6	4.152	96.9	86.1	91.5	74.0	4.129	93.1	87.3	90.2
23320.0	1.50	42.6	4.388	58.4	49.2	53.8	45.6	4.374	59.3	51.1	55.2	47.6	4.342	61.0	55.5	58.3
23372.8	1.51	63.0	4.196	70.9	80.8	75.9	55.9	4.306	66.6	70.0	68.3	51.5	4.350	59.1	67.6	63.4
23425.6	1.52	72.3	4.528	106.1	55.2	80.6	70.8	4.520	96.1	58.9	77.5	69.5	4.455	95.5	64.1	79.8
23478.4	1.53	44.1	4.362	47.9	64.5	56.2	39.5	4.447	41.2	53.0	47.1	49.3	4.442	59.1	61.8	60.5
23531.2	1.54	42.8	4.299	37.4	71.0	54.2	40.6	4.307	35.7	73.9	54.8	39.5	4.312	31.7	73.8	52.7
23584.0	1.55	44.6	4.407	50.4	49.8	50.1	44.5	4.428	50.0	54.0	52.0	43.0	4.492	50.9	50.9	50.9
23636.8	1.56	86.6	4.030	120.4	111.7	116.0	86.8	4.015	123.4	110.7	117.1	92.0	3.881	132.7	126.0	129.4
23689.6	1.57	62.6	4.063	98.6	91.7	95.2	60.5	4.172	95.1	90.6	92.8	57.1	4.245	82.7	84.7	83.7
23742.4	1.58	44.1	4.233	50.5	79.4	64.9	45.8	4.188	55.7	82.5	69.1	50.0	4.136	50.8	92.8	71.8
23795.2	1.59	35.3	4.249	37.2	64.7	51.0	35.7	4.247	35.8	61.6	48.7	37.5	4.277	30.1	65.9	48.0
23848.0	1.60	33.4	4.402	40.1	52.8	46.5	30.6	4.436	38.9	49.8	44.3	29.7	4.442	39.0	46.9	42.9
23900.8	1.61	33.3	4.308	40.4	57.1	48.7	30.9	4.327	40.5	56.0	48.3	28.6	4.411	31.6	55.7	43.7
23953.6	1.62	44.3	4.121	41.3	80.0	60.6	48.1	4.033	39.8	86.1	63.0	42.9	4.188	37.0	78.2	57.6
24006.4	1.63	47.6	4.117	56.1	85.5	70.8	48.3	4.092	49.0	87.4	68.2	42.0	4.157	48.2	74.6	61.4
24059.2	1.64	32.7	4.288	32.8	58.2	45.5	32.7	4.285	28.4	56.0	42.2	31.6	4.341	27.2	60.2	43.7
24112.0	1.65	41.6	4.348	56.3	61.5	58.9	38.9	4.339	54.9	57.2	56.0	37.2	4.332	54.5	56.7	55.6
24164.8	1.66	42.2	4.128	35.4	84.2	59.8	47.9	4.061	37.6	92.3	64.9	35.9	4.307	36.5	65.2	50.9
24217.6	1.67	44.7	4.225	63.7	66.9	65.3	43.5	4.269	64.0	65.0	64.5	38.7	4.322	52.7	60.3	56.5
24270.4	1.68	51.1	4.035	46.2	84.1	65.2	49.3	4.048	38.7	81.8	60.2	48.5	4.055	40.9	84.6	62.7
24323.2	1.69	38.0	4.224	30.8	65.3	48.1	36.5	4.352	28.8	64.3	46.5	33.0	4.353	29.6	63.4	46.5
24376.0	1.70	40.6	4.360	45.3	63.0	54.2	46.3	4.147	47.3	74.9	61.1	43.1	4.271	42.9	64.1	53.5
24428.8	1.71	51.4	4.389	56.3	60.8	58.5	58.9	4.310	62.7	73.0	67.8	59.5	4.364	62.0	67.4	64.7
24481.6	1.72	53.5	4.513	72.9	52.6	62.8	48.2	4.505	69.2	52.3	60.8	46.2	4.523	69.0	45.8	57.4
24534.4	1.73	30.7	4.447	43.3	45.4	44.3	31.0	4.486	43.0	43.1	43.1	29.1	4.520	43.6	46.4	45.0
24587.2	1.74	31.5	4.337	52.0	54.1	53.1	29.7	4.356	51.7	59.4	55.5	32.6	4.339	46.5	62.3	54.4
24640.0	1.75	52.6	4.276	64.9	69.2	67.0	54.6	4.216	66.7	69.8	68.2	46.4	4.372	59.0	58.0	58.5
24692.8	1.76	62.4	4.146	66.8	79.5	73.1	58.8	4.215	63.5	72.7	68.1	61.8	4.122	61.2	84.2	72.7
24745.6	1.77	42.1	4.188	36.6	72.0	54.3	39.3	4.164	38.8	69.9	54.4	34.9	4.304	32.8	56.4	44.6
24798.4	1.78	46.9	4.212	42.7	73.9	58.3	45.1	4.223	45.1	69.8	57.4	50.4	4.113	44.2	81.2	62.7
24851.2	1.79	29.4	4.355	49.6	57.9	53.7	31.4	4.306	56.0	58.7	57.4	31.9	4.359	45.5	57.6	51.5
24904.0	1.80	44.3	4.171	40.2	84.8	62.5	45.1	4.168	40.9	84.2	62.6	46.4	4.230	32.5	86.1	59.3
24956.8	1.81	53.7	4.168	56.0	90.5	73.2	48.9	4.222	52.8	81.0	66.9	49.7	4.240	62.6	74.7	68.6
25009.6	1.82	43.1	4.077	27.1	82.8	55.0	44.2	4.064	26.1	82.8	54.4	37.6	4.141	22.6	76.0	49.3
25062.4	1.83	30.0	4.372	34.4	50.9	42.7	33.4	4.240	33.3	59.1	46.2	31.1	4.303	33.2	55.5	44.3
25115.2	1.84	61.4	4.221	88.5	79.5	74.0	65.0	4.218	67.3	80.4	73.8	64.9	4.203	68.4	82.9	75.7
25168.0	1.85	36.2	4.235	57.6	71.6	64.6	37.1	4.241	58.3	70.9	64.6	36.5	4.070	58.1	69.1	63.6
25220.8	1.86	42.1	4.306	60.6	64.4	62.5	38.1	4.351	60.5	67.8	64.2	42.0	4.311	61.3	62.8	62.1
25273.6	1.87	37.0	4.264	39.6	64.2	51.9	32.7	4.338	40.5	54.4	47.5	39.1	4.116	38.8	70.1	54.5
25326.4	1.88	43.8	4.106	45.3	75.5	60.4	40.0	4.170	42.6	73.5	58.1	41.6	4.155	42.5	70.9	56.7
25379.2	1.89	33.6	4.412	38.3	56.1	47.2	33.7	4.440	43.7	50.2	47.0	36.3	4.382	41.3	56.7	49.0
25432.0	1.90	34.1	4.410	43.2	55.5	49.4	31.5	4.438	45.7	45.4	45.5	33.1	4.460	45.1	52.4	48.7
25484.8	1.91	34.8	4.424	37.8	52.4	45.1	29.3	4.516	36.2	44.6	40.4	39.0	4.362	44.6	59.0	51.8
25537.6	1.92	41.0	4.214	41.6	77.4	59.5	41.4	4.217	39.4	71.9	55.7	42.9	4.177	38.9	75.9	57.4
25590.4	1.93	46.3	4.308	53.4	65.1	59.2	47.2	4.340	52.5	65.7	59.1	53.8	4.266	67.3	70.0	68.6
25643.2	1.94	53.0	4.425	80.1	53.4	66.7	51.0	4.441	68.8	52.7	60.7	50.0	4.350	64.8	65.1	64.9
25696.0	1.95	61.1	4.406	90.3	66.0	78.1	65.3	4.361	84.0	70.6	77.3	64.1	4.261	82.8	74.5	78.6
25748.8	1.96	27.1	4.512	24.3	52.7	38.5	33.0	4.418	26.2	64.2	45.2	33.9	4.390	28.3	64.1	46.2
25801.6	1.97	54.3	4.297	70.1	71.9	71.0	58.8	4.245	68.6	79.4	74.0	61.2	4.146	68.6	88.5	78.5
25854.4	1.98	41.8	4.333	44.6	59.4	52.0	47.2	4.271	56.2	61.0	58.6	47.9	4.173	57.7	66.4	62.0
25907.2	1.99	56.8	4.433	79.3	54.8	67.1	74.1	4.392	109.8	71.7	90.7	78.5	4.312	120.1	69.7	94.9
25960.0	2.00	43.1	4.337	44.0	54.6	49.3	44.5	4.218	40.3	68.1	54.2	40.1	4.327	35.7	60.6	48.1
26012.8	2.01	35.4	4.441	36.6	51.0	43.8	37.9	4.371	43.1	57.6	50.3	38.4	4.258	43.9	64.7	54.3
26065.6	2.02	45.2	4.094	40.1	85.8	62.9	46.2	4.044	39.8	83.1	61.5	52.5	3.982	39.9	95.3	67.6
26118.4	2.03	34.4	4.330	29.3	59.4	44.3	39.4	4.172	31.7	73.4	52.6	41.8	4.150	31.2	76.7	54.0

26171.2	2.04	31.5	4.367	30.8	57.1	43.9	31.8	4.352	25.7	63.7	44.7	29.7	4.337	30.5	61.5	46.0
26224.0	2.05	51.9	4.121	49.8	87.3	68.5	57.2	4.124	52.7	90.8	71.7	53.3	4.105	53.3	89.8	71.6
26276.8	2.06	62.9	4.226	67.7	92.1	79.9	63.9	4.295	70.8	79.9	75.3	61.2	4.255	64.5	80.4	72.5
26329.6	2.07	67.0	4.227	69.5	81.1	75.3	68.8	4.110	67.9	87.0	77.5	77.3	4.087	71.6	95.8	83.7
26382.4	2.08	99.8	3.985	129.1	120.6	124.9	95.0	4.135	130.8	103.1	117.0	85.4	4.089	121.1	106.4	113.7
26435.2	2.09	101.3	4.046	132.2	91.7	112.0	112.4	4.090	139.8	98.7	119.2	99.1	4.073	131.9	91.7	111.8
26488.0	2.10	73.4	4.184	81.0	91.4	86.2	68.4	4.274	69.5	91.0	80.2	63.8	4.320	59.7	88.5	74.1
26540.8	2.11	40.1	4.237	40.1	81.9	61.0	33.2	4.281	33.6	74.0	53.8	39.3	4.183	40.8	82.8	61.8
26593.6	2.12	51.6	4.061	53.9	97.3	75.6	47.5	4.124	51.3	90.4	70.9	45.6	4.137	51.1	85.9	68.5
26646.4	2.13	41.8	4.082	33.8	82.4	58.1	40.4	4.062	29.2	80.8	55.0	48.5	4.031	31.8	92.8	62.3
26699.2	2.14	63.7	4.013	42.8	113.3	78.1	57.0	4.044	49.2	98.0	73.6	65.7	3.923	43.4	114.7	79.1
26752.0	2.15	48.1	4.135	20.7	85.0	52.8	40.9	4.293	21.5	69.0	45.3	48.4	4.122	20.7	82.2	51.5
26804.8	2.16	46.4	4.169	34.1	82.8	58.5	42.3	4.220	33.2	75.3	54.3	45.4	4.185	40.0	81.0	60.5
26857.6	2.17	47.9	4.024	41.0	87.7	64.4	41.7	4.207	39.0	68.2	53.6	52.8	3.968	42.2	97.8	70.0
26910.4	2.18	44.0	4.156	37.0	80.9	58.9	38.7	4.262	34.6	72.7	53.6	43.0	4.102	38.6	84.8	61.7
26963.2	2.19	57.2	4.003	39.9	97.8	68.8	51.4	4.175	49.4	85.5	67.4	56.6	4.083	42.1	93.7	67.9
27016.0	2.20	30.9	4.403	36.2	53.9	45.0	32.0	4.378	34.6	60.9	47.8	28.9	4.340	36.4	53.8	45.1
27068.8	2.21	40.0	4.263	28.2	68.4	48.3	34.3	4.399	29.8	58.5	44.2	38.4	4.401	32.8	61.2	47.0
27121.6	2.22	47.3	4.381	48.2	58.4	53.3	52.4	4.302	49.8	67.4	58.6	49.9	4.235	51.2	62.6	58.9
27174.4	2.23	49.1	4.293	62.3	81.0	71.7	50.2	4.319	69.1	82.4	75.8	44.7	4.414	63.8	76.0	69.9
27227.2	2.24	46.8	4.481	59.8	54.5	57.2	49.4	4.461	59.1	54.1	56.6	50.4	4.350	60.3	64.9	62.6
27280.0	2.25	48.2	4.299	58.7	73.6	66.1	40.7	4.309	51.0	72.7	61.8	44.3	4.347	51.8	75.6	63.7
27332.8	2.26	32.4	4.435	47.1	53.2	50.1	40.7	4.388	47.1	63.6	55.3	33.0	4.402	45.1	55.8	50.4
27385.6	2.27	40.5	4.354	38.0	63.4	50.7	41.2	4.368	41.9	55.0	48.4	37.3	4.465	40.2	51.6	45.9
27438.4	2.28	43.4	4.119	27.5	77.9	52.7	42.3	4.180	28.9	74.2	51.6	46.9	4.128	30.7	82.0	56.4
27491.2	2.29	48.7	4.091	33.9	95.9	64.9	40.5	4.289	29.6	75.6	52.6	38.5	4.305	31.1	76.7	53.9
27544.0	2.30	47.7	4.047	58.1	86.6	72.3	39.4	4.229	57.2	72.2	64.7	45.6	4.133	59.9	82.0	71.0
27596.8	2.31	43.0	4.330	40.9	73.0	57.0	42.4	4.452	43.2	60.4	51.8	48.4	4.237	48.4	73.6	61.0
27649.6	2.32	65.5	4.080	77.0	80.8	78.9	56.9	4.199	62.0	76.4	69.2	57.7	4.116	69.7	76.6	73.1
27702.4	2.33	27.0	4.563	34.0	43.4	38.7	26.1	4.568	26.4	49.2	37.8	29.5	4.575	36.7	45.5	41.1
27755.2	2.34	56.9	4.424	70.5	62.0	66.3	55.0	4.480	67.7	56.3	62.0	64.7	4.490	86.2	55.4	70.8
27808.0	2.35	42.3	4.530	68.9	45.2	57.1	41.2	4.527	61.5	44.3	52.9	35.0	4.556	60.1	44.7	52.4
27860.8	2.36	53.2	4.211	64.7	68.7	66.7	57.1	4.188	62.0	76.2	69.1	55.2	4.212	64.5	73.0	68.7
27913.6	2.37	34.6	4.445	24.1	54.0	39.1	31.0	4.402	26.1	48.4	37.2	31.9	4.402	22.9	53.7	38.3
27966.4	2.38	34.2	4.322	46.6	58.8	52.7	39.3	4.271	44.7	63.9	54.3	39.4	4.256	46.9	66.5	56.7
28019.2	2.39	54.5	4.328	51.0	67.8	59.4	55.0	4.237	53.1	69.3	61.2	59.2	4.181	59.8	72.5	66.2
28072.0	2.40	54.9	4.264	64.4	65.9	65.1	49.2	4.362	63.1	55.1	59.1	45.4	4.365	54.1	53.4	53.8
28124.8	2.41	30.7	4.387	22.0	52.5	37.3	29.1	4.468	23.9	48.6	36.3	29.7	4.400	20.2	55.2	37.7
28177.6	2.42	23.7	4.496	31.5	38.3	34.9	24.1	4.488	30.8	38.4	34.6	24.6	4.534	31.2	36.8	34.0
28230.4	2.43	31.1	4.446	37.0	49.8	43.4	33.7	4.372	35.4	50.8	43.1	35.8	4.354	40.6	56.7	48.6
28283.2	2.44	28.9	4.348	47.7	56.6	52.1	31.2	4.441	47.9	58.7	53.3	27.1	4.454	48.8	50.5	49.6
28336.0	2.45	32.4	4.338	30.4	51.6	41.0	36.6	4.239	33.6	53.4	43.5	39.8	4.143	28.1	65.7	46.9
28388.8	2.46	54.5	3.977	34.1	97.5	65.8	44.4	4.172	34.5	73.5	54.0	44.0	4.161	34.9	71.3	53.1
28441.6	2.47	31.2	4.368	32.7	55.1	43.9	35.9	4.235	31.2	58.5	44.8	36.2	4.310	32.2	63.5	47.9
28494.4	2.48	41.8	4.311	40.1	62.8	51.5	40.5	4.334	41.7	59.2	50.4	40.2	4.314	43.0	54.1	48.6
28547.2	2.49	51.3	4.193	49.9	70.3	60.1	53.4	4.161	50.1	72.9	61.5	52.3	4.245	48.6	75.7	62.1
28600.0	2.50	31.0	4.464	36.4	42.9	39.6	32.5	4.504	40.3	43.7	42.0	30.7	4.446	36.4	44.0	40.2
28652.8	2.51	32.9	4.425	35.2	60.7	48.0	32.6	4.424	37.5	59.1	48.3	33.4	4.418	34.9	58.5	46.7
28705.6	2.52	30.3	4.425	37.5	49.4	43.4	36.2	4.454	39.3	57.5	48.4	41.4	4.399	46.6	53.4	50.0
28758.4	2.53	62.9	4.278	85.9	62.1	74.0	65.5	4.246	90.2	61.5	75.8	66.6	4.281	92.0	62.7	77.3
28811.2	2.54	79.0	4.056	85.2	93.7	89.4	73.0	4.045	75.8	95.8	85.8	71.4	4.001	72.1	100.5	86.3
28864.0	2.55	74.7	4.086	77.6	87.6	82.6	80.2	3.980	75.4	100.8	88.1	79.0	4.053	83.9	91.4	87.7
28916.8	2.56	33.6	4.436	38.1	52.2	45.2	37.4	4.349	34.4	60.1	47.2	41.4	4.131	32.0	70.3	51.1
28969.6	2.57	57.6	4.099	61.0	84.8	72.9	59.0	4.041	65.1	86.6	75.8	56.8	4.180	74.3	82.9	78.6
29022.4	2.58	25.6	4.632	58.1	49.9	54.0	32.2	4.533	74.8	63.4	69.1	50.2	4.164	54.3	103.1	78.7

ATH050R  
 10JUN98  
 K.J. Law Profilometer  
 Model 690DNC

Run 1 Down  
 ATHUSA.001

Run 2 Down  
 ATHUSC.003

Run 3 Down  
 ATHUSD.005

Station	Miles	MAYS	PSI	IRIlf	IRIrt	IRIbh	MAYS	PSI	IRIlf	IRIrt	IRIbh	MAYS	PSI	IRIlf	IRIrt	IRIbh
29000.0	0.00															
28947.2	0.01	67.5	4.010	55.0	107.6	81.3	67.4	3.961	52.1	109.6	80.8	63.6	3.974	51.5	107.1	79.3
28894.4	0.02	45.6	4.152	66.2	70.9	68.5	49.6	4.143	68.9	77.3	73.1	47.2	4.148	69.3	71.5	70.4
28841.6	0.03	45.9	4.091	28.9	81.1	55.0	43.5	4.115	23.6	80.6	52.1	42.3	4.123	29.7	76.7	53.2
28788.8	0.04	41.5	4.309	44.3	71.0	57.7	44.5	4.295	48.1	77.2	62.7	46.0	4.276	49.7	80.8	65.3
28736.0	0.05	43.9	4.351	60.3	61.3	60.8	40.9	4.362	48.6	59.1	53.9	44.1	4.282	52.8	67.4	60.1
28683.2	0.06	37.9	4.386	45.6	66.4	56.0	43.6	4.244	45.2	78.7	62.0	43.6	4.245	44.5	79.9	62.2
28630.4	0.07	25.2	4.478	27.9	44.0	36.0	29.0	4.402	28.9	51.5	40.2	30.2	4.340	27.0	55.8	41.4
28577.6	0.08	32.4	4.286	24.1	57.6	40.8	30.9	4.389	22.6	52.1	37.4	29.8	4.373	21.2	53.5	37.4
28524.8	0.09	58.3	3.953	52.0	101.7	76.8	53.0	4.073	49.2	91.2	70.2	48.3	4.162	50.1	79.3	64.7
28472.0	0.10	60.1	4.017	53.7	94.1	73.9	57.3	4.050	54.6	89.9	72.2	53.0	4.111	56.7	77.1	66.9
28419.2	0.11	56.5	4.123	39.5	106.6	73.1	53.7	4.151	44.6	103.6	74.1	54.0	4.130	47.5	97.9	72.7
28366.4	0.12	51.6	4.205	37.1	78.9	58.0	56.6	4.149	39.9	84.3	62.1	51.4	4.291	44.1	71.4	57.8
28313.6	0.13	47.5	4.468	55.6	56.7	56.1	50.9	4.433	58.8	58.8	58.8	48.1	4.428	56.3	55.0	55.7
28260.8	0.14	46.2	4.246	44.4	75.7	60.1	47.4	4.157	43.1	77.6	60.4	41.9	4.260	41.0	67.1	54.1
28208.0	0.15	40.4	4.309	39.3	73.4	56.3	36.9	4.409	41.1	64.4	52.7	39.8	4.363	42.5	68.6	55.5
28155.2	0.16	41.4	4.317	44.6	65.4	55.0	38.2	4.377	42.8	54.7	48.8	38.8	4.384	42.8	55.6	49.2
28102.4	0.17	40.6	4.381	44.8	72.4	58.6	38.5	4.434	43.4	59.8	51.6	37.6	4.409	45.5	61.1	53.3
28049.6	0.18	40.5	4.231	35.7	75.6	55.7	34.5	4.274	32.9	65.0	49.0	36.4	4.228	34.5	69.0	51.7
27996.8	0.19	43.2	4.299	44.1	69.7	56.9	46.3	4.190	43.9	76.6	60.2	45.0	4.268	41.7	75.4	58.6
27944.0	0.20	53.5	4.027	57.0	88.8	72.9	52.6	4.114	57.7	81.1	69.4	55.1	4.120	58.1	85.3	71.7
27891.2	0.21	36.0	4.274	31.8	64.2	48.0	39.4	4.237	35.7	70.8	53.3	39.1	4.229	34.6	70.3	52.4
27838.4	0.22	54.3	4.078	33.6	102.8	68.2	51.3	4.098	38.9	95.9	67.4	45.6	4.130	40.0	81.6	60.8
27785.6	0.23	37.1	4.466	57.6	66.4	62.0	34.0	4.454	57.4	57.2	57.3	32.8	4.481	53.0	54.7	53.8
27732.8	0.24	62.7	4.321	63.3	88.9	76.1	60.7	4.416	67.0	77.7	72.4	61.2	4.381	67.9	77.0	72.5
27680.0	0.25	45.4	4.334	55.1	66.8	61.0	43.2	4.415	56.5	59.1	57.8	45.7	4.357	54.4	64.3	59.4
27627.2	0.26	69.2	4.132	72.2	106.7	89.4	67.1	4.161	71.7	101.9	86.8	70.5	4.147	71.4	111.8	91.6
27574.4	0.27	101.9	4.091	125.4	110.0	117.7	101.6	4.067	119.2	115.7	117.5	107.1	4.079	124.3	121.5	122.9
27521.6	0.28	54.5	4.279	61.4	79.1	70.2	56.4	4.200	57.4	85.3	71.3	55.5	4.236	59.8	83.4	71.6
27468.8	0.29	61.4	4.156	71.9	78.0	74.9	64.9	4.137	72.9	85.6	79.3	62.4	4.072	69.0	90.0	79.5
27416.0	0.30	59.4	4.153	66.1	89.6	77.8	60.8	4.063	63.0	91.7	77.4	62.1	4.094	70.0	87.4	78.7
27363.2	0.31	49.1	4.130	46.8	80.8	63.8	44.1	4.158	42.2	80.1	61.1	45.3	4.207	47.0	81.4	64.2
27310.4	0.32	31.3	4.383	31.6	68.3	50.0	34.0	4.288	27.0	73.1	50.0	32.5	4.392	21.1	67.2	44.2
27257.6	0.33	50.5	4.194	43.1	93.8	68.5	52.2	4.167	50.3	99.7	75.0	50.1	4.195	49.0	95.3	72.1
27204.8	0.34	68.3	4.331	81.1	88.8	85.0	70.0	4.250	78.6	99.5	89.1	65.9	4.307	74.6	95.2	84.9
27152.0	0.35	41.5	4.332	55.1	73.0	64.1	41.2	4.386	59.8	66.5	63.1	42.1	4.348	60.4	67.6	64.0
27099.2	0.36	49.9	4.208	49.5	72.5	61.0	51.1	4.240	51.7	71.8	61.8	48.5	4.155	43.1	84.0	63.6
27046.4	0.37	46.6	4.236	66.1	78.8	72.4	43.8	4.258	65.8	79.9	72.8	45.6	4.232	67.9	84.9	76.4
26993.6	0.38	47.5	4.227	43.1	86.1	64.6	44.1	4.314	47.4	76.6	62.0	46.5	4.247	52.1	79.2	65.6

26940.8	0.39	50.7	4.079	37.7	89.1	63.4	51.5	4.135	37.4	87.3	62.4	51.9	4.123	36.6	87.7	62.2
26888.0	0.40	46.9	4.347	58.5	58.8	58.7	50.8	4.332	59.6	63.3	61.5	49.9	4.374	60.9	60.5	60.7
26835.2	0.41	44.0	4.163	28.6	85.4	57.0	47.8	4.058	28.3	93.4	60.9	46.4	4.104	26.5	93.0	59.7
26782.4	0.42	57.6	4.288	78.6	69.0	73.8	64.1	4.197	85.9	80.0	82.9	61.8	4.194	83.6	78.0	80.8
26729.6	0.43	48.8	4.102	43.4	87.8	65.6	48.2	4.075	40.2	93.2	66.7	48.9	4.080	44.1	96.1	70.1
26676.8	0.44	50.0	4.109	56.5	89.6	73.1	55.3	4.081	61.2	92.9	77.1	56.0	4.046	58.6	98.0	78.3
26624.0	0.45	44.5	4.139	18.7	84.5	51.6	49.0	4.060	20.0	94.3	57.1	48.1	4.098	18.0	94.5	56.3
26571.2	0.46	55.8	4.198	58.8	101.7	80.2	55.0	4.228	56.0	97.5	76.7	58.4	4.192	61.2	102.7	82.0
26518.4	0.47	54.4	4.107	63.0	94.6	78.8	58.3	4.004	61.8	102.0	81.9	54.6	4.113	65.4	93.8	79.6
26465.6	0.48	55.0	4.128	40.3	107.2	73.8	54.6	4.136	46.2	107.1	76.7	53.6	4.152	48.2	104.5	76.4
26412.8	0.49	83.6	4.153	101.4	104.7	103.1	89.8	4.068	105.4	111.3	108.3	86.8	4.119	100.9	110.2	105.5
26360.0	0.50	91.5	4.042	118.4	109.8	114.1	92.8	3.854	110.0	132.3	121.1	90.4	3.980	111.5	119.0	115.2
26307.2	0.51	82.6	4.117	128.9	86.4	107.6	74.8	4.200	125.3	82.3	103.8	80.5	4.166	124.4	82.2	103.3
26254.4	0.52	66.5	4.023	64.9	98.9	81.9	56.1	4.159	54.7	85.2	70.0	66.9	4.049	63.9	106.0	84.9
26201.6	0.53	56.8	4.034	74.5	95.9	85.2	65.5	4.064	83.2	104.4	93.8	59.3	4.028	75.1	98.6	86.8
26148.8	0.54	44.6	4.145	30.1	86.1	58.1	47.5	4.127	32.0	86.5	59.2	49.8	4.091	30.9	90.1	60.5
26096.0	0.55	62.0	3.868	40.0	116.2	78.1	56.2	3.982	42.0	111.8	76.9	61.7	3.843	41.7	120.9	81.3
26043.2	0.56	50.8	3.978	33.6	94.7	64.1	57.0	3.962	40.9	101.4	71.1	58.2	3.907	38.8	102.9	70.8
25990.4	0.57	58.5	4.144	71.9	94.0	82.9	60.3	4.162	76.6	90.3	83.5	58.9	4.101	68.4	99.8	84.1
25937.6	0.58	41.9	4.188	35.8	73.5	54.6	41.0	4.188	33.4	72.6	53.0	41.5	4.118	29.7	74.0	51.9
25884.8	0.59	67.8	3.863	40.8	125.3	83.0	64.7	3.947	39.3	118.4	78.8	69.1	3.883	44.6	124.5	84.6
25832.0	0.60	73.0	4.001	71.4	96.0	83.7	67.9	4.057	66.6	97.5	82.0	75.5	3.998	70.9	107.4	89.2
25779.2	0.61	68.7	4.111	85.7	88.8	87.2	71.5	4.066	95.3	86.3	90.8	68.6	4.083	85.4	87.9	86.7
25726.4	0.62	62.8	3.804	70.4	126.7	98.5	63.2	3.812	68.1	128.1	98.1	63.9	3.862	72.2	122.3	97.3
25673.6	0.63	76.9	4.050	76.0	115.1	95.6	75.0	4.060	79.3	110.9	95.1	74.1	4.070	81.3	107.2	94.3
25620.8	0.64	101.1	3.947	115.4	124.2	119.8	103.0	3.854	111.9	136.0	124.0	102.7	3.937	112.4	131.0	121.7
25568.0	0.65	70.8	4.031	78.7	93.1	85.9	68.7	4.073	77.4	84.4	80.9	70.0	3.976	74.7	93.1	83.9
25515.2	0.66	68.7	3.780	50.1	128.7	89.4	61.2	3.911	63.9	106.7	85.3	67.0	3.821	56.9	127.5	92.2
25462.4	0.67	53.6	4.041	43.4	108.2	75.8	53.1	4.007	41.5	102.2	71.9	50.6	4.096	38.5	101.1	69.8
25409.6	0.68	52.4	4.055	55.6	97.2	76.4	52.1	4.049	57.0	97.0	77.0	56.2	4.036	60.9	101.4	81.2
25356.8	0.69	49.3	4.138	43.1	100.4	71.8	50.4	4.099	42.6	107.0	74.8	46.9	4.171	43.5	95.8	69.7
25304.0	0.70	54.9	3.882	46.4	108.4	77.4	60.7	3.828	46.4	116.5	81.4	53.5	3.960	46.5	103.2	74.9
25251.2	0.71	41.9	4.240	50.4	80.0	65.2	35.9	4.352	50.5	72.7	61.6	41.3	4.239	50.8	86.3	68.6
25198.4	0.72	62.1	3.952	52.2	132.9	92.5	61.3	4.043	49.1	120.6	84.8	62.4	3.977	42.1	126.9	84.5
25145.6	0.73	86.4	3.495	119.8	177.7	148.8	77.3	3.650	121.0	164.5	142.7	85.6	3.488	120.3	181.7	151.0
25092.8	0.74	113.3	3.835	144.6	123.9	134.2	108.9	3.860	141.0	125.1	133.0	114.1	3.841	146.8	121.9	134.4
25040.0	0.75	56.5	4.246	103.0	87.4	95.2	52.4	4.302	94.6	84.2	89.4	57.7	4.228	99.6	99.0	99.3
24987.2	0.76	58.4	3.891	30.5	116.2	73.4	66.1	3.742	35.2	129.2	82.2	62.4	3.869	33.5	122.5	78.0
24934.4	0.77	52.8	4.155	48.3	104.3	76.3	53.3	4.118	49.4	103.8	76.6	59.4	4.071	48.3	115.3	81.8
24881.6	0.78	51.3	4.033	44.3	101.8	73.1	54.4	4.005	44.9	111.0	78.0	50.2	4.039	43.2	108.0	75.6
24828.8	0.79	53.7	4.002	53.9	110.7	82.3	57.3	3.900	56.9	114.1	85.5	55.0	3.905	54.0	120.4	87.2
24776.0	0.80	61.9	3.930	42.3	118.6	80.4	65.2	3.887	45.8	126.7	86.3	65.8	3.934	47.0	122.7	84.9
24723.2	0.81	89.3	4.043	93.3	104.1	98.7	89.3	4.041	91.1	104.3	97.7	89.1	4.106	93.2	103.8	98.5
24670.4	0.82	65.2	4.070	105.0	90.4	97.7	63.8	4.079	102.2	90.8	96.5	62.1	4.159	101.7	80.2	90.9
24617.6	0.83	64.0	4.015	64.6	107.4	86.0	62.0	4.028	61.9	108.5	85.2	62.1	4.016	61.0	113.7	87.3
24564.8	0.84	66.9	4.082	89.6	93.8	91.7	68.6	4.095	91.7	93.7	92.7	67.1	4.126	86.0	88.4	87.2
24512.0	0.85	47.8	4.329	60.5	84.3	72.4	48.7	4.268	62.3	87.8	75.1	44.3	4.365	61.3	79.1	70.2
24459.2	0.86	44.8	4.075	43.3	104.1	73.7	46.1	4.014	46.6	108.5	77.6	45.9	4.053	44.8	106.5	75.7
24406.4	0.87	64.8	3.966	60.9	110.2	85.5	69.5	3.918	62.9	111.7	87.3	69.6	3.874	61.7	110.8	86.3
24353.6	0.88	67.2	3.860	70.5	117.4	94.0	67.7	3.795	72.1	124.6	98.3	68.3	3.797	68.3	124.8	96.6
24300.8	0.89	50.4	4.024	36.1	97.1	66.6	58.9	3.883	38.0	109.5	73.7	61.4	3.819	34.7	116.7	75.7
24248.0	0.90	56.8	4.033	49.7	108.1	78.9	53.8	3.989	45.4	107.7	76.6	59.4	3.967	46.7	112.9	79.8
24195.2	0.91	72.7	3.921	67.5	126.9	97.2	74.4	3.861	72.5	124.8	98.6	80.2	3.733	72.8	133.5	103.1
24142.4	0.92	79.4	3.929	97.3	127.3	112.3	77.9	4.088	104.2	110.3	107.3	71.0	4.205	103.5	92.4	98.0
24089.6	0.93	53.4	4.123	64.2	93.3	78.7	57.1	4.042	60.8	95.6	78.2	52.9	4.115	57.8	87.3	72.6

24038.8	0.94	58.0	3.967	40.3	108.3	74.3	54.5	4.064	42.7	100.5	71.6	49.6	4.097	38.9	90.2	64.5
23984.0	0.95	67.6	3.870	66.7	114.4	90.6	68.4	3.838	63.2	121.9	92.5	72.0	3.793	64.1	125.6	94.9
23931.2	0.96	51.7	4.093	50.4	105.3	77.9	56.8	4.067	49.3	110.3	79.8	54.7	4.079	51.7	106.1	78.9
23878.4	0.97	50.9	4.042	57.4	99.1	78.3	47.9	4.050	57.9	95.0	76.5	48.3	4.086	61.2	96.5	78.8
23825.6	0.98	36.1	4.404	59.9	75.5	67.7	37.1	4.379	61.4	74.2	67.8	36.4	4.415	59.4	74.4	66.9
23772.8	0.99	75.5	3.940	79.9	119.0	99.5	73.3	3.777	65.0	129.8	97.4	71.9	3.881	69.1	121.8	95.5
23720.0	1.00	58.2	4.070	78.5	110.4	94.5	65.9	3.891	71.7	121.5	96.6	60.4	3.995	70.2	112.8	91.5
23667.2	1.01	52.1	4.017	50.5	100.3	75.4	56.6	3.933	56.7	99.3	78.0	52.9	4.033	55.3	94.5	74.9
23614.4	1.02	113.9	4.031	135.7	136.2	136.0	116.8	3.920	142.7	134.7	138.7	117.5	4.048	139.8	132.4	136.1
23561.6	1.03	81.0	4.134	99.4	90.2	94.8	84.4	4.130	100.3	95.5	97.9	83.9	4.024	92.9	106.1	99.5
23508.8	1.04	56.5	4.008	47.1	102.7	74.9	48.8	4.176	39.2	77.9	58.5	61.9	3.984	49.1	104.5	76.8
23456.0	1.05	46.6	4.254	43.6	79.8	61.7	42.6	4.259	48.2	73.2	60.7	46.8	4.160	41.9	84.3	63.1
23403.2	1.06	62.8	4.211	105.7	73.6	89.6	62.7	4.360	100.3	69.1	84.7	62.4	4.252	110.2	71.6	90.9
23350.4	1.07	75.2	4.057	100.6	105.1	102.8	74.3	4.219	97.9	79.5	88.7	76.0	4.072	102.0	94.1	98.1
23297.6	1.08	72.1	4.021	66.1	99.7	82.9	75.1	4.066	67.1	99.1	83.1	72.8	4.032	71.6	98.7	85.1
23244.8	1.09	89.3	3.918	90.9	122.1	106.5	86.3	3.941	96.1	113.1	104.6	92.2	3.883	94.6	124.4	109.5
23192.0	1.10	67.4	4.244	91.4	72.7	82.1	66.4	4.240	86.6	78.8	82.7	64.8	4.246	87.4	70.3	78.9
23086.4	1.11	38.0	4.398	43.1	56.9	51.0	38.0	4.441	40.4	59.3	49.9	36.7	4.404	41.0	58.8	49.9
23033.6	1.12	30.7	4.462	46.7	49.0	47.9	31.0	4.431	47.0	41.6	44.3	29.1	4.414	45.8	40.5	43.1
22980.8	1.13	48.3	4.302	70.0	66.6	68.3	47.7	4.321	69.4	65.0	67.2	49.1	4.312	69.2	66.8	68.0
22928.0	1.14	32.7	4.425	42.1	53.2	47.7	35.5	4.336	40.8	59.5	50.2	36.5	4.331	41.9	58.7	50.3
22875.2	1.15	46.9	4.272	58.6	71.3	64.9	45.1	4.288	57.9	69.5	63.7	46.3	4.272	59.9	75.1	67.5
22822.4	1.16	47.3	4.200	57.5	72.8	65.2	49.4	4.182	57.2	79.8	68.5	49.1	4.191	56.4	80.2	68.3
22769.6	1.17	37.4	4.257	39.5	64.4	52.0	38.7	4.253	38.6	67.5	53.0	38.7	4.236	35.7	71.6	53.6
22716.8	1.18	54.8	4.171	56.6	90.1	73.4	51.9	4.133	56.4	87.6	72.0	53.7	4.074	51.8	95.7	73.7
22664.0	1.19	41.7	4.235	30.9	72.6	51.8	42.4	4.202	23.2	77.0	50.1	45.8	4.146	23.5	83.6	53.6
22611.2	1.20	33.4	4.358	32.0	66.3	49.1	30.5	4.385	30.5	57.3	43.9	28.7	4.450	28.5	55.8	42.1
22558.4	1.21	21.3	4.537	21.5	38.0	29.8	20.5	4.536	22.5	47.4	30.1	17.7	4.598	22.1	33.6	27.8
22505.6	1.22	43.4	4.235	39.4	83.3	61.3	35.9	4.325	42.4	65.8	54.1	34.4	4.367	43.0	59.9	51.5
22452.8	1.23	53.1	4.066	50.4	94.0	72.2	51.3	4.117	52.9	89.0	71.0	53.5	4.094	56.7	90.0	73.4
22400.0	1.24	48.7	4.276	54.9	74.2	64.5	48.8	4.272	51.8	70.5	61.2	48.1	4.253	46.6	74.9	60.7
22347.2	1.25	49.1	4.157	32.2	92.5	62.3	45.8	4.202	36.6	85.3	60.5	44.6	4.196	31.1	87.2	59.2
22294.4	1.26	52.5	4.223	63.5	71.8	67.7	55.5	4.217	64.6	78.3	71.4	55.1	4.194	63.1	79.3	71.2
22241.6	1.27	80.7	4.232	111.6	79.5	95.6	84.4	4.256	120.3	76.6	98.5	82.7	4.243	117.5	79.6	98.6
22188.8	1.28	41.3	4.279	51.2	67.2	59.2	41.1	4.276	52.6	68.5	60.5	39.8	4.247	43.9	75.9	59.9
22136.0	1.29	37.8	4.311	52.9	70.1	61.5	57.4	4.281	68.5	73.8	71.2	60.2	4.206	67.0	83.5	75.3
22083.2	1.30	57.7	4.288	66.2	75.0	70.6	47.7	4.396	71.0	64.4	67.7	47.5	4.437	71.1	61.9	66.5
22030.4	1.31	48.1	4.402	74.5	64.6	69.5	47.7	4.396	71.0	64.4	67.7	47.5	4.437	71.1	61.9	66.5
21977.6	1.32	36.8	4.484	55.8	67.2	61.5	33.2	4.525	56.1	62.0	59.1	29.9	4.526	49.6	62.5	56.0
21924.8	1.33	33.6	4.545	62.0	58.2	60.1	34.7	4.520	64.1	55.6	59.9	34.2	4.522	62.7	58.1	60.4
21872.0	1.34	51.7	4.296	64.5	67.2	65.9	47.7	4.362	59.9	63.0	61.5	48.7	4.281	54.7	64.2	59.4
21819.2	1.35	49.1	4.202	50.8	89.5	70.1	46.3	4.272	55.7	73.9	64.8	51.8	4.204	49.9	91.8	70.9
21766.4	1.36	49.1	4.392	57.9	64.9	61.4	41.2	4.460	52.9	53.1	53.0	47.9	4.374	52.1	66.2	59.2
21713.6	1.37	42.1	3.962	32.2	81.7	57.0	31.3	4.252	35.1	52.9	44.0	36.5	4.162	35.0	65.2	50.1
21660.8	1.38	31.4	4.338	52.9	56.8	54.8	32.7	4.270	54.1	58.3	56.2	31.8	4.206	50.7	61.7	56.2
21608.0	1.39	51.3	4.054	49.3	99.2	74.2	28.1	4.342	43.9	47.1	45.5	43.2	4.227	51.9	79.1	65.5
21555.2	1.40	45.6	3.699	41.3	81.2	61.3	36.5	4.178	43.8	67.1	55.5	35.5	4.204	42.0	59.3	50.6
21502.4	1.41	43.3	4.182	43.5	69.9	56.7	54.3	3.796	47.8	99.9	73.8	60.8	3.731	53.5	109.6	81.6
21449.6	1.42	41.8	4.119	45.3	73.8	59.5	43.3	3.796	47.8	99.9	73.8	66.8	3.357	47.2	116.4	81.8
21396.8	1.43	90.7	3.002	57.2	175.0	116.1	79.1	3.250	52.3	152.5	102.4	69.9	3.312	37.9	128.0	83.0
21344.0	1.44	68.1	3.418	31.7	127.4	79.6	50.5	3.773	33.7	91.6	62.7	49.6	3.792	49.5	83.7	66.6
21291.2	1.45	50.8	3.615	47.7	85.6	66.6	33.6	4.411	44.4	56.3	50.3	26.6	4.461	39.2	47.7	43.5
21238.4	1.46	23.0	4.533	41.9	44.9	43.4	23.8	4.483	36.7	48.6	42.7	21.9	4.557	17.4	49.1	33.2
21185.6	1.47	22.2	4.522	20.8	56.9	38.8	26.6	4.451	19.0	57.6	38.3	21.9	4.557	17.4	49.1	33.2

21132.8	1.49	33.1	4.498	55.2	70.7	62.9	33.7	4.534	57.0	66.1	61.6	32.6	4.533	60.8	58.8	59.8
21080.0	1.50	37.3	4.584	58.7	37.8	48.2	34.9	4.551	50.6	40.1	45.3	36.1	4.505	51.9	40.2	46.1
21027.2	1.51	24.7	4.539	48.4	57.1	52.7	24.5	4.541	55.9	59.0	57.5	24.1	4.478	57.8	63.0	60.4
20974.4	1.52	34.2	4.360	45.7	69.0	57.4	35.6	4.336	41.4	65.7	53.5	41.2	4.240	36.5	74.4	55.4
20921.6	1.53	29.5	4.214	38.5	71.3	54.9	33.4	4.191	35.3	69.7	52.5	34.2	4.262	37.5	70.1	53.8
20868.8	1.54	41.3	4.372	52.5	68.9	60.7	37.6	4.486	54.7	57.4	56.1	32.4	4.473	43.0	57.6	50.3
20816.0	1.55	44.6	4.482	62.5	52.6	57.6	46.0	4.503	58.6	52.7	55.7	43.8	4.464	53.8	57.3	55.5
20763.2	1.56	49.4	4.277	72.9	74.3	73.6	46.9	4.413	65.3	67.4	66.3	45.2	4.345	65.8	66.7	66.3
20710.4	1.57	53.8	4.064	59.2	88.1	73.7	46.9	4.216	59.8	75.6	67.7	57.3	3.982	63.4	99.7	81.5
20657.6	1.58	64.9	4.415	76.0	72.5	74.3	62.5	4.429	70.0	70.1	70.1	71.6	4.391	82.6	76.8	79.7
20604.8	1.59	54.5	4.329	73.5	67.9	70.7	57.3	4.198	62.1	90.7	76.4	52.3	4.199	62.5	84.2	73.4
20552.0	1.60	45.8	4.210	64.1	84.0	74.1	45.8	4.184	58.8	92.9	75.8	49.8	4.098	55.4	93.3	74.3
20499.2	1.61	50.7	4.094	49.8	93.9	71.9	48.7	4.092	57.9	86.4	72.1	55.6	4.039	52.9	104.2	78.5
20446.4	1.62	45.8	4.379	50.6	75.5	63.0	39.8	4.473	56.9	53.0	54.9	40.9	4.395	52.3	63.7	58.0
20393.6	1.63	42.0	4.205	42.4	71.4	56.9	42.2	4.248	52.2	64.2	58.2	36.7	4.311	46.9	62.2	54.5
20340.8	1.64	54.1	4.050	53.1	94.9	74.0	48.9	4.138	55.2	77.3	66.3	54.9	4.047	45.2	100.9	73.1
20288.0	1.65	49.1	4.062	33.0	97.9	65.4	50.2	4.121	42.9	94.0	68.4	53.9	4.038	38.2	104.1	71.2
20235.2	1.66	42.2	4.103	56.2	83.9	70.1	44.0	4.125	54.3	86.6	70.5	45.1	4.162	51.4	90.3	70.9
20182.4	1.67	84.7	4.224	104.9	109.2	107.0	75.8	4.209	104.8	103.8	104.3	85.2	4.232	115.1	104.2	109.7
20129.6	1.68	56.7	4.223	72.8	66.5	69.7	72.3	3.893	72.4	103.3	87.9	73.6	3.820	76.1	107.2	91.7
20076.8	1.69	42.6	4.312	49.2	74.4	61.8	64.3	3.957	61.3	113.0	87.2	70.3	3.905	58.1	130.4	94.3
20024.0	1.70	47.2	4.170	59.3	82.5	70.9	50.8	4.112	61.9	88.1	75.0	57.0	3.969	61.2	111.0	86.1
19971.2	1.71	54.7	4.043	49.4	106.0	77.7	46.6	4.111	51.4	84.0	67.7	58.7	3.980	48.1	113.0	80.6
19918.4	1.72	64.7	3.973	49.2	121.6	85.4	58.2	4.060	64.8	97.4	81.1	67.0	3.933	46.6	122.0	84.3
19865.6	1.73	87.2	4.208	124.3	94.8	109.6	89.8	4.205	128.2	92.6	110.4	88.7	4.216	129.7	92.4	111.0
19812.8	1.74	59.7	4.072	88.8	92.1	90.5	61.6	4.096	94.2	78.0	86.1	58.8	4.092	79.1	91.3	85.2
19760.0	1.75	56.1	4.077	43.4	96.6	70.0	48.8	4.081	39.9	84.7	62.3	54.6	4.153	52.3	88.4	70.3
19707.2	1.76	55.4	3.926	35.6	104.2	69.9	57.7	3.900	32.1	108.7	70.4	52.1	3.980	39.9	93.4	66.7
19654.4	1.77	40.6	4.330	57.1	68.5	62.8	42.3	4.349	62.7	61.2	61.9	39.5	4.375	60.4	64.7	62.5
19601.6	1.78	49.2	4.008	35.2	98.4	66.8	38.1	4.178	42.8	76.6	59.7	50.9	3.970	37.1	95.9	66.5
19548.8	1.79	52.1	4.110	39.8	110.3	75.0	41.4	4.211	37.0	78.0	57.5	49.3	4.103	34.9	97.3	66.1
19496.0	1.80	41.2	4.073	28.7	83.6	56.1	37.6	4.120	23.8	74.2	49.0	45.2	4.009	25.6	90.1	57.8
19443.2	1.81	57.4	4.130	64.6	100.6	82.6	49.7	4.257	59.7	79.4	69.5	53.0	4.149	62.0	91.9	76.9
19390.4	1.82	47.9	4.178	42.5	81.4	62.0	41.6	4.348	46.5	62.8	54.7	46.2	4.313	38.0	70.6	54.3
19337.6	1.83	52.4	4.273	63.1	82.1	72.6	45.8	4.394	54.6	65.6	60.1	43.8	4.447	62.0	56.0	59.0
19284.8	1.84	46.3	4.330	67.9	82.9	75.4	37.1	4.518	61.8	55.6	58.7	38.3	4.375	61.1	81.7	71.4
19232.0	1.85	36.8	4.248	35.8	74.4	55.1	38.8	4.304	34.5	70.1	52.3	38.5	4.279	29.1	69.2	49.2
19179.2	1.86	32.6	4.281	46.1	67.4	56.7	36.0	4.243	46.9	66.2	56.5	33.4	4.271	45.4	66.0	55.7
19126.4	1.87	43.2	4.212	57.9	84.0	71.0	44.3	4.198	58.4	87.3	72.9	43.5	4.204	55.5	84.6	70.1
19073.6	1.88	43.2	4.279	53.5	68.4	60.9	45.0	4.250	47.2	69.5	58.3	45.9	4.235	49.2	70.0	59.6
19020.8	1.89	52.0	4.515	79.9	57.7	68.8	51.2	4.484	86.0	58.7	72.3	49.6	4.483	79.0	62.4	70.7
18968.0	1.90	50.7	4.188	61.6	85.1	73.4	49.2	4.232	57.4	79.0	68.2	52.9	4.122	54.6	84.1	69.4
18915.2	1.91	59.1	4.272	75.0	74.0	74.5	60.6	4.282	71.1	76.1	73.6	58.8	4.284	73.2	74.6	73.9
18862.4	1.92	43.1	4.135	64.1	89.6	76.9	42.6	4.142	63.9	86.4	75.1	44.9	4.113	68.1	93.0	80.6
18809.6	1.93	38.2	4.299	48.6	63.3	55.9	41.3	4.265	43.1	72.5	57.8	46.3	4.252	46.2	83.5	64.9
18756.8	1.94	54.7	4.049	28.8	106.1	67.4	61.7	3.984	38.5	115.0	76.8	68.2	3.923	38.8	123.4	81.1
18704.0	1.95	67.0	3.983	79.8	105.3	92.5	61.3	4.042	74.8	101.0	87.9	63.1	3.920	75.7	108.1	91.9
18651.2	1.96	73.6	4.248	80.6	93.2	86.9	74.2	4.243	80.3	90.4	85.3	71.8	4.166	85.9	86.4	86.2
18598.4	1.97	64.6	4.338	87.1	73.3	80.2	64.1	4.359	92.2	66.7	79.4	55.4	4.349	67.7	70.4	69.0
18545.6	1.98	85.9	4.198	103.2	87.6	95.4	85.3	4.125	103.0	90.6	96.8	84.8	4.044	99.5	98.8	99.2
18492.8	1.99	93.3	4.294	136.3	80.2	108.3	91.5	4.250	135.5	78.8	107.2	81.8	4.245	113.0	77.6	95.3
18440.0	2.00	65.3	4.199	81.4	81.6	81.5	62.9	4.160	80.0	80.7	80.4	57.4	4.173	75.1	81.1	78.1
18387.2	2.01	36.7	4.474	46.7	54.2	50.5	42.7	4.352	44.3	70.3	57.3	40.7	4.376	52.3	61.5	56.9
18334.4	2.02	37.0	4.390	31.5	63.3	47.4	49.3	4.205	33.7	82.4	58.1	36.7	4.332	30.8	66.7	48.7
18281.6	2.03	36.4	4.179	34.0	61.9	47.9	37.2	4.322	37.6	65.9	51.7	38.7	4.206	28.3	69.1	48.7

18228.8	2.04	39.6	4.337	37.1	68.9	53.0	41.7	4.232	36.2	75.0	55.6	41.5	4.173	39.1	73.0	56.0
18176.0	2.05	41.4	4.179	43.5	82.9	63.2	44.3	4.155	45.5	95.6	70.6	50.1	3.949	45.6	103.6	74.6
18123.2	2.06	50.5	4.012	45.5	83.3	64.4	55.5	3.966	45.8	92.5	69.1	64.5	3.829	54.5	106.9	80.7
18070.4	2.07	40.7	4.161	22.0	76.4	49.2	39.7	4.162	21.6	73.7	47.7	41.4	4.201	31.8	76.3	54.1
18017.6	2.08	43.2	4.407	55.4	62.2	58.8	45.2	4.419	55.6	67.0	61.3	44.6	4.383	62.5	57.9	60.2
17964.8	2.09	33.3	4.436	36.9	50.7	43.8	33.9	4.422	37.9	54.8	46.3	36.3	4.396	42.9	53.5	48.2
17912.0	2.10	45.3	4.205	37.6	74.4	56.0	44.8	4.204	39.3	73.9	56.6	44.0	4.204	41.8	72.9	57.4
17859.2	2.11	38.6	4.258	45.0	67.0	56.0	37.9	4.296	38.1	65.3	51.7	40.0	4.318	48.0	56.3	52.1
17806.4	2.12	30.9	4.359	39.2	51.6	45.4	31.3	4.340	39.9	53.7	46.8	40.0	4.291	44.9	58.4	51.6
17753.6	2.13	41.8	4.332	29.9	68.5	49.2	38.1	4.399	28.8	58.6	43.7	38.0	4.391	38.5	59.6	49.1
17700.8	2.14	53.5	4.297	66.4	81.4	73.9	53.2	4.279	64.3	84.5	74.4	54.9	4.263	67.7	73.0	70.4
17648.0	2.15	44.2	4.147	25.9	85.4	55.6	45.5	4.067	29.3	87.9	58.6	49.2	4.040	33.2	98.7	66.0
17595.2	2.16	41.1	4.152	62.5	78.4	70.4	42.8	4.181	65.7	83.5	74.6	50.7	4.024	60.0	103.8	81.9
17542.4	2.17	57.4	4.255	56.1	91.3	73.7	59.0	4.187	51.2	98.0	74.6	61.5	4.181	54.2	102.2	78.2
17489.6	2.18	46.3	4.282	47.8	91.8	69.8	50.1	4.247	52.5	97.0	74.8	49.1	4.274	50.8	90.4	70.6
17436.8	2.19	78.6	3.781	105.2	120.9	113.1	72.3	3.786	102.8	118.9	110.9	65.6	3.893	90.6	114.6	102.6
17384.0	2.20	43.8	4.145	39.3	73.3	56.3	49.0	4.097	39.2	81.4	60.3	52.1	4.093	36.9	87.5	62.2
17331.2	2.21	48.7	4.145	32.9	92.1	62.5	37.0	4.230	33.8	73.1	53.4	43.0	4.136	29.3	82.9	56.1
17278.4	2.22	37.9	4.247	33.6	68.6	51.1	43.3	4.217	35.4	74.8	55.1	44.5	4.168	28.3	80.3	54.3
17225.6	2.23	52.2	4.343	56.9	70.7	63.8	50.3	4.347	63.0	64.0	63.5	52.0	4.340	64.9	63.8	64.3
17172.8	2.24	52.7	4.195	62.4	82.4	72.4	50.7	4.186	55.5	72.8	64.1	55.1	4.106	55.1	73.4	64.2
17120.0	2.25	73.3	4.214	85.7	89.2	87.5	66.2	4.290	83.9	72.6	78.3	65.0	4.292	86.2	69.5	77.8
17067.2	2.26	87.8	4.119	112.1	96.9	104.5	85.9	4.173	113.1	95.2	104.1	89.1	4.106	116.2	100.3	108.2
17014.4	2.27	72.3	4.168	77.4	95.9	86.7	69.5	4.182	77.7	86.5	82.1	74.9	4.043	80.1	101.0	90.6
16961.6	2.28	75.7	3.904	72.1	119.4	95.7	79.2	3.835	69.1	126.9	98.0	73.0	3.853	66.2	126.2	96.2
16908.8	2.29	49.9	4.239	52.8	83.8	68.3	46.6	4.311	53.7	76.8	65.3	48.7	4.267	53.8	81.6	67.7
16856.0	2.30	60.6	4.161	75.8	91.4	83.6	67.8	4.092	90.2	94.3	92.2	64.4	4.079	83.5	103.5	93.5
16803.2	2.31	41.1	4.303	34.5	67.1	50.8	37.6	4.321	32.0	70.1	51.0	39.5	4.290	30.3	66.6	48.5
16750.4	2.32	34.9	4.372	36.6	64.9	50.7	32.1	4.382	41.8	61.0	51.4	35.5	4.338	35.9	69.5	52.7
16697.6	2.33	28.9	4.420	22.1	50.5	36.3	29.4	4.430	26.8	51.4	39.1	31.8	4.354	28.7	52.6	40.7
16644.8	2.34	52.6	3.986	24.2	97.7	60.9	53.2	4.000	24.6	98.0	61.3	52.1	3.997	26.7	94.4	60.6
16592.0	2.35	49.9	4.110	26.5	96.2	61.4	50.1	4.065	23.1	96.3	59.7	50.6	3.960	27.7	96.5	62.1
16539.2	2.36	68.3	4.000	66.0	100.4	83.2	67.7	3.969	61.9	102.6	82.2	67.1	4.063	66.1	90.7	78.4
16486.4	2.37	44.6	4.068	33.3	85.4	59.4	51.0	3.953	35.5	98.5	67.0	57.8	3.893	39.1	107.6	73.4
16433.6	2.38	54.3	3.961	24.2	98.9	61.6	47.7	4.164	27.9	79.7	53.8	43.1	4.196	30.9	69.2	50.1
16380.8	2.39	59.5	3.933	39.3	112.8	76.0	55.9	3.934	30.0	108.9	69.4	53.1	4.001	30.2	100.6	65.4
16328.0	2.40	52.3	4.129	58.9	90.9	74.9	61.2	4.042	63.5	100.5	82.0	59.7	4.034	60.9	98.0	79.5
16275.2	2.41	43.5	4.137	36.2	79.4	57.8	43.6	4.127	35.8	82.4	59.1	47.5	4.138	37.4	84.0	60.7
16222.4	2.42	42.6	4.248	37.2	77.0	57.1	36.7	4.300	35.4	67.7	51.6	36.3	4.309	35.6	68.7	52.2
16169.6	2.43	56.9	3.976	45.6	99.2	72.4	55.4	4.028	46.9	95.4	71.1	55.6	3.959	45.7	97.1	71.4
16116.8	2.44	29.0	4.486	40.0	49.7	44.8	30.9	4.448	34.3	54.3	44.3	34.4	4.454	33.5	59.5	46.5
16064.0	2.45	43.8	4.226	43.7	72.0	57.9	46.9	4.170	37.9	83.8	60.9	50.2	4.136	36.6	88.1	62.4
16011.2	2.46	44.8	4.170	51.1	72.7	61.9	44.5	4.161	48.6	71.7	60.2	47.1	4.145	46.8	79.7	63.3
15958.4	2.47	45.7	4.065	31.9	84.0	58.0	51.6	3.968	29.6	96.3	62.9	52.8	3.943	32.5	101.6	67.1
15905.6	2.48	44.8	4.202	36.3	81.0	58.7	41.3	4.234	33.8	75.1	54.5	44.8	4.197	35.5	84.1	59.8
15852.8	2.49	38.6	4.171	36.3	67.8	52.1	47.0	4.103	43.5	84.7	64.1	46.0	4.145	38.9	80.1	59.5
15800.0	2.50	34.8	4.288	31.8	61.1	46.5	37.2	4.296	36.7	66.3	51.5	34.7	4.241	30.4	65.8	48.1
15747.2	2.51	42.2	4.256	40.1	71.9	56.0	41.4	4.244	40.2	77.0	58.6	36.3	4.359	38.9	62.0	50.5
15694.4	2.52	48.4	4.480	66.8	54.0	60.4	48.5	4.404	66.8	57.1	61.9	48.8	4.475	66.6	55.5	61.1
15641.6	2.53	47.3	4.473	68.9	54.7	61.8	51.7	4.371	66.5	59.8	63.2	45.1	4.442	60.7	55.2	57.9
15588.8	2.54	25.8	4.501	42.0	46.0	44.0	28.1	4.523	42.3	42.3	42.3	25.5	4.561	42.0	39.7	40.8
15536.0	2.55	30.6	4.265	31.6	48.5	40.1	30.2	4.297	27.4	49.9	38.6	30.8	4.268	23.4	55.0	39.2
15483.2	2.56	48.1	4.175	48.2	77.3	62.7	50.4	4.131	50.9	81.7	66.3	48.6	4.142	50.4	78.3	64.3
15430.4	2.57	40.7	4.044	36.8	77.6	57.2	43.8	4.002	33.2	83.6	58.4	47.1	3.966	32.9	91.7	62.3
15377.6	2.58	46.2	4.202	40.6	86.8	63.7	41.8	4.463	54.7	80.2	67.4	49.1	4.208	44.1	86.8	65.4

